34TH CONGRESS, 3d *Session.* | HOUSE OF REPRESENTATIVES. | MIS. DOC. No. 55.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION, FOR THE YEAR 1856.

AND THE

PROCEEDINGS OF THE BOARD UP TO JANUARY 28, 1857.

WASHINGTON:
CORNELIUS WENDELL, PRINTER.
1857.

LETTER

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

COMMUNICATING

The Annual Report of the Board of Regents.

FEBRUARY 18, 1857.—Ordered to be printed.

MARCH 3, 1857.—*Resolved*, That there be printed of the Report of the Regents of the Smithsonian Institution 10,000 copies; 7,500 for the use of the members of the House, and 2,500 for the use of the Institution.

SMITHSONIAN INSTITUTION,
Washington, February 17, 1857.

SIR: In behalf of the Board of Regents, I have the honor to submit to the House of Representatives of the United States the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year 1856.

I have the honor to be, very respectfully, your obedient servant,

JOSEPH HENRY,
Secretary Smithsonian Institution.

Hon. NATHANIEL P. BANKS, Jr.,
Speaker of the House of Representatives.

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION, UP TO JANUARY 1, 1857, AND THE PROCEEDINGS OF THE BOARD UP TO JANUARY 28, 1857.

To the Senate and House of Representatives:

In obedience to the act of Congress of August 10, 1846, establishing the Smithsonian Institution, the undersigned, in behalf of the Regents, submit to Congress, as a Report of the operations, expenditures, and condition of the Institution, the following documents:

1. The Annual Report of the Secretary, giving an account of the operations of the Institution during the year 1856.
2. Report of the Executive Committee, giving a general statement of the proceeds and disposition of the Smithsonian fund, and also an account of the expenditures for the year 1856.
3. Report of the Building Committee for 1856.
4. Proceedings of the Board of Regents up to January 28, 1857.
5. Appendix.

Respectfully submitted:

R. B. TANEY, *Chancellor.*
JOSEPH HENRY, *Secretary.*

OFFICERS OF THE SMITHSONIAN INSTITUTION

JAMES BUCHANAN, *Ex officio* Presiding Officer of the Institution.
ROGER B. TANEY, Chancellor of the Institution.

JOSEPH HENRY, Secretary of the Institution.
SPENCER F. BAIRD, Assistant Secretary.
W. W. SEATON, Treasurer.
WILLIAM J. RHEES, Chief Clerk.

ALEXANDER D. BACHE,
JAMES A. PEARCE,
JOSEPH G. TOTTEN, } Executive Committee.

RICHARD RUSH,
WILLIAM H. ENGLISH,
JOSEPH HENRY, } Building Committee.

REGENTS OF THE INSTITUTION.

JOHN C. BRECKENRIDGE, Vice President of the United States.
ROGER B. TANEY, Chief Justice of the United States.
WM. B. MAGRUDER, Mayor of the City of Washington.
JAMES A. PEARCE, member of the Senate of the United States.
JAMES M. MASON, member of the Senate of the United States.
STEPHEN A. DOUGLAS, member of the Senate of the United States.
WILLIAM H. ENGLISH, member of the House of Representatives.
HIRAM WARNER, member of the House of Representatives.
BENJAMIN STANTON, member of the House of Representatives.
GIDEON HAWLEY, citizen of New York.
RICHARD RUSH, citizen of Pennsylvania.
GEORGE E. BADGER, citizen of North Carolina.
CORNELIUS C. FELTON, citizen of Massachusetts.
ALEXANDER D. BACHE, citizen of Washington.
JOSEPH G. TOTTEN, citizen of Washington.

MEMBERS EX OFFICIO OF THE INSTITUTION.

JAMES BUCHANAN, President of the United States.
JOHN C. BRECKENRIDGE, Vice President of the United States.
LEWIS CASS, Secretary of State.
HOWELL COBB, Secretary of the Treasury.
JOHN B. FLOYD, Secretary of War.
ISAAC TOUCEY, Secretary of the Navy.
AARON V. BROWN, Postmaster General.
JAMES BLACK, Attorney General.
ROGER B. TANEY, Chief Justice of the United States.
CHARLES MASON, Commissioner of Patents.
WM. B. MAGRUDER, Mayor of the City of Washington.

HONORARY MEMBERS.

ROBERT HARE, of Pennsylvania.
WASHINGTON IRVING, of New York
BENJAMIN SILLIMAN, of Connecticut.
PARKER CLEAVELAND, of Maine.
A. B. LONGSTREET, of Mississippi.

PROGRAMME OF ORGANIZATION

OF THE

SMITHSONIAN INSTITUTION.

[PRESENTED IN THE FIRST ANNUAL REPORT OF THE SECRETARY, AND ADOPTED BY THE BOARD OF REGENTS, DECEMBER 13, 1847.]

INTRODUCTION.

General considerations which should serve as a guide in adopting a Plan of Organization.

1. WILL OF SMITHSON. The property is bequeathed to the United States of America, "to found at Washington, under the name of the SMITHSONIAN INSTITUTION, an establishment for the increase and diffusion of knowledge among men."

2. The bequest is for the benefit of mankind. The government of the United States is merely a trustee to carry out the design of the testator.

3. The Institution is not a national establishment, as is frequently supposed, but the establishment of an individual, and is to bear and perpetuate his name.

4. The objects of the Institution are, 1st, to increase, and 2d, to diffuse knowledge among men.

5. These two objects should not be confounded with one another. The first is to enlarge the existing stock of knowledge by the addition of new truths; and the second, to disseminate knowledge, thus increased, among men.

6. The will makes no restriction in favor of any particular kind of knowledge; hence all branches are entitled to a share of attention.

7. Knowledge can be increased by different methods of facilitating and promoting the discovery of new truths; and can be most extensively diffused among men by means of the press.

8. To effect the greatest amount of good, the organization should be such as to enable the Institution to produce results, in the way of increasing and diffusing knowledge, which cannot be produced either at all or so efficiently by the existing institutions in our country.

9. The organization should also be such as can be adopted provisionally, can be easily reduced to practice, receive modifications, or be abandoned, in whole or in part, without a sacrifice of the funds.

10. In order to compensate, in some measure, for the loss of time occasioned by the delay of eight years in establishing the institution,

a considerable portion of the interest which has accrued should be added to the principal.

11. In proportion to the wide field of knowledge to be cultivated, the funds are small. Economy should therefore be consulted in the construction of the building; and not only the first cost of the edifice should be considered, but also the continual expense of keeping it in repair, and of the support of the establishment necessarily connected with it. There should also be but few individuals permanently supported by the Institution.

12. The plan and dimensions of the building should be determined by the plan of the organization, and not the converse.

13. It should be recollected that mankind in general are to be benefited by the bequest, and that, therefore, all unnecessary expenditure on local objects would be a perversion of the trust.

14. Besides the foregoing considerations, deduced immediately from the will of Smithson, regard must be had to certain requirements of the act of Congress establishing the Institution. These are, a library, a museum, and a gallery of art, with a building on a liberal scale to contain them.

SECTION I.

Plan of Organization of the Institution in accordance with the foregoing deductions from the Will of Smithson.

To Increase Knowledge. It is proposed—

1. To stimulate men of talent to make original researches, by offering suitable rewards for memoirs containing new truths; and,

2. To appropriate annually a portion of the income for particular researches, under the direction of suitable persons.

To Diffuse Knowledge. It is proposed—

1. To publish a series of periodical reports on the progress of the different branches of knowledge; and,

2. To publish occasionally separate treatises on subjects of general interest.

DETAILS OF THE PLAN TO INCREASE KNOWLEDGE.

I. *By stimulating researches.*

1. Facilities afforded for the production of original memoirs on all branches of knowledge.

2. The memoirs thus obtained to be published in a series of volumes, in a quarto form, and entitled Smithsonian Contributions to Knowledge.

3. No memoir, on subjects of physical science, to be accepted for publication, which does not furnish a positive addition to human knowledge, resting on original research; and all unverified speculations to be rejected.

4. Each memoir presented to the Institution to be submitted for examination to a commission of persons of reputation for learning in

the branch to which the memoir pertains; and to be accepted for publication only in case the report of this commission is favorable.

5. The commission to be chosen by the officers of the Institution, and the name of the author, as far as practicable, concealed, unless a favorable decision be made.

6. The volumes of the memoirs to be exchanged for the Transactions of literary and scientific societies, and copies to be given to all the colleges, and principal libraries, in this country. One part of the remaining copies may be offered for sale; and the other carefully preserved, to form complete sets of the work, to supply the demand from new institutions.

7. An abstract, or popular account, of the contents of these memoirs to be given to the public through the annual report of the Regents to Congress.

II. *By appropriating a part of the income, annually, to special objects of research, under the direction of suitable persons.*

1. The objects, and the amount appropriated, to be recommended by counsellors of the Institution.

2. Appropriations in different years to different objects; so that in course of time each branch of knowledge may receive a share.

3. The results obtained from these appropriations to be published, with the memoirs before mentioned, in the volumes of the Smithsonian Contributions to Knowledge.

4. Examples of objects for which appropriations may be made.

(1.) System of extended meteorological observations for solving the problem of American storms.

(2.) Explorations in descriptive natural history, and geological, magnetical, and topographical surveys, to collect materials for the formation of a Physical Atlas of the United States.

(3.) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity, and of light; chemical analyses of soils and plants; collection and publication of scientific facts, accumulated in the offices of government.

(4.) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5.) Historical researches, and accurate surveys of places celebrated in American history.

(6.) Ethnological researches, particularly with reference to the different races of men in North America; also, explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

DETAILS OF THE PLAN FOR DIFFUSING KNOWLEDGE.

I. *By the publication of a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge not strictly professional.*

1. These reports will diffuse a kind of knowledge generally interesting, but which, at present, is inaccessible to the public. Some

of the reports may be published annually, others at longer intervals, as the income of the Institution or the changes in the branches of knowledge may indicate.

2. The reports are to be prepared by collaborators, eminent in the different branches of knowledge.

3. Each collaborator to be furnished with the journals and publications, domestic and foreign, necessary to the compilation of his report; to be paid a certain sum for his labors, and to be named on the title-page of the report.

4. The reports to be published in separate parts, so that persons interested in a particular branch can procure the parts relating to it without purchasing the whole.

5. These reports may be presented to Congress, for partial distribution, the remaining copies to be given to literary and scientific institutions, and sold to individuals for a moderate price.

The following are some of the subjects which may be embraced in the reports:*

I. PHYSICAL CLASS.

1. Physics, including astronomy, natural philosophy, chemistry, and meteorology.
2. Natural history, including botany, zoology, geology, &c.
3. Agriculture.
4. Application of science to arts.

II. MORAL AND POLITICAL CLASS.

5. Ethnology, including particular history, comparative philology, antiquities, &c.
6. Statistics and political economy.
7. Mental and moral philosophy.
8. A survey of the political events of the world; penal reform, &c.

III. LITERATURE AND THE FINE ARTS.

9. Modern literature
10. The fine arts, and their application to the useful arts.
11. Bibliography.
12. Obituary notices of distinguished individuals.

II. *By the publication of separate treatises on subjects of general interest.*

1. These treatises may occasionally consist of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution, or procured by offering premiums for the best exposition of a given subject.

2. The treatises should, in all cases, be submitted to a commission of competent judges, previous to their publication.

* This part of the plan has been but partially carried out.

3. As examples of these treatises, expositions may be obtained of the present state of the several branches of knowledge mentioned in the table of reports.

SECTION II.

Plan of organization, in accordance with the terms of the resolutions of the Board of Regents providing for the two modes of increasing and diffusing knowledge.

1. The act of Congress establishing the Institution contemplated the formation of a library and a museum; and the Board of Regents, including these objects in the plan of organization, resolved to divide the income* into two equal parts.

2. One part to be appropriated to increase and diffuse knowledge by means of publications and researches, agreeably to the scheme before given. The other part to be appropriated to the formation of a library and a collection of objects of nature and of art.

3. These two plans are not incompatible with one another.

4. To carry out the plan before described, a library will be required, consisting, 1st, of a complete collection of the transactions and proceedings of all the learned societies in the world; 2d, of the more important current periodical publications, and other works necessary in preparing the periodical reports.

5. The Institution should make special collections, particularly of objects to illustrate and verify its own publications.

6. Also, a collection of instruments of research in all branches of experimental science.

7. With reference to the collection of books, other than those mentioned above, catalogues of all the different libraries in the United States should be procured, in order that the valuable books first purchased may be such as are not to be found in the United States.

8. Also, catalogues of memoirs, and of books and other materials, should be collected for rendering the Institution a centre of bibliographical knowledge, whence the student may be directed to any work which he may require.

9. It is believed that the collections in natural history will increase by donation as rapidly as the income of the Institution can make provision for their reception, and, therefore, it will seldom be necessary to purchase articles of this kind.

10. Attempts should be made to procure for the gallery of art, casts of the most celebrated articles of ancient and modern sculpture.

11. The arts may be encouraged by providing a room, free of expense, for the exhibition of the objects of the Art-Union and other similar societies.

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* The amount of the Smithsonian bequest received into the Treasury of the United States is	$515,169 00
Interest on the same to July 1, 1846, (devoted to the erection of the building,)	242,129 00
Annual income from the bequest	30,910 14

12. A small appropriation should annually be made for models of antiquities, such as those of the remains of ancient temples, &c.

13. For the present, or until the building is fully completed, besides the Secretary, no permanent assistant will be required, except one, to act as librarian.

14. The Secretary, by the law of Congress, is alone responsible to the Regents. He shall take charge of the building and property, keep a record of proceedings, discharge the duties of librarian and keeper of the museum, and may, with the consent of the Regents, *employ assistants*.

15. The Secretary and his assistants, during the session of Congress, will be required to illustrate new discoveries in science, and to exhibit new objects of art; distinguished individuals should also be invited to give lectures on subjects of general interest.

This programme, which was at first adopted provisionally, has become the settled policy of the Institution. The only material change is that expressed by the following resolutions, adopted January 15, 1855, viz:

Resolved, That the 7th resolution passed by the Board of Regents, on the 26th of January, 1847, requiring an equal division of the income between the active operations and the museum and library, when the buildings are completed, be and it is hereby repealed.

Resolved, That hereafter the annual appropriations shall be apportioned specifically among the different objects and operations of the Institution, in such manner as may, in the judgment of the Regents, be necessary and proper for each, according to its intrinsic importance, and a compliance in good faith with the law.

REPORT OF THE SENATE JUDICIARY COMMITTEE.*

The following is the report presented in the Senate on the 6th February, 1855, by Judge Butler, from the Committee on the Judiciary, to whom was referred the inquiry whether any, and if any, what, action of the Senate is necessary and proper in regard to the Smithsonian Institution:

"It seems to be the object of the resolution to require the committee to say whether, in its opinion, the Regents of the Smithsonian Institution have given a fair and proper construction, within the range of discretion allowed to them, to the acts of Congress putting into operation the trust which Mr. Smithson had devolved on the federal government. As the trust has not been committed to a legal corporation subject to judicial jurisdiction and control, it must be regarded as the creature of congressional legislation. It is a naked and hon-

* Messrs. Butler, Toucey, Bayard, Geyer, Pettit, and Toombs.

orable trust, without any profitable interest in the government that has undertaken to carry out the objects of the benevolent testator. The obligations of good faith require that the bequest should be maintained in the spirit in which it was made. The acts of Congress on this subject were intended to effect this end, and the question presented is this: Have the Regents done their duty according to the requirements of the acts of Congress on the subject?

"In order to determine whether any, and if any, what, action of the Senate is necessary and proper in regard to the Smithsonian Institution, it is necessary to examine what provisions Congress have already made on the subject, and whether they have been faithfully carried into execution.

"The money with which this Institution has been founded was bequeathed to the United States by James Smithson, of London, to found at Washington, under the name of the 'Smithsonian Institution,' an establishment 'for the increase and diffusion of knowledge among men.' It is not bequeathed to the United States to be used for their own benefit and advantage only, but in trust to apply to 'the increase and diffusion of knowledge' among mankind generally, so that other men and other nations might share in its advantage as well as ourselves.

"Congress accepted the trust, and by the act of August 10, 1846, established an institution to carry into effect the intention of the testator. The language of the will left a very wide discretion in the manner of executing the trust, and different opinions might very naturally be entertained on the subject. And it is very evident by the law above referred to that Congress did not deem it advisable to prescribe any definite and fixed plan, and deemed it more proper to confide that duty to a Board of Regents, carefully selected, indicating only in general terms the objects to which their attention was to be directed in executing the testator's intention.

"Thus, by the fifth section, the Regents were required to cause a building to be erected of sufficient size, and with suitable rooms or halls, for the reception and arrangement, upon a liberal scale, of objects of natural history, including a geological and mineralogical cabinet; also a chemical laboratory, a library, a gallery of art, and the necessary lecture-rooms. It is evident that Congress intended by these provisions that the funds of the institution should be applied to increase knowledge in all of the branches of science mentioned in this section—in objects of natural history, in geology, in mineralogy, in chemistry, in the arts—and that lectures were to be delivered upon such topics as the Regents might deem useful in the execution of the trust. And publications by the institution were undoubtedly necessary to diffuse generally the knowledge that might be obtained; for any increase of knowledge that might thus be acquired was not to be locked up in the institution or preserved only for the use of the citizens of Washington, or persons who might visit the institution. It was by the express terms of the trust, which the United States was pledged to execute, to be diffused among men. This could be done in no other way than by publications at the expense of the Institution. Nor has Congress prescribed the sums which shall be appro-

priated to these different objects. It is left to the discretion and judgment of the Regents.

"The fifth section also requires a library to be formed, and the eighth section provides that the Regents shall make from the interest an appropriation, not exceeding an average of twenty-five thousand dollars annually, for the gradual formation of a library composed of valuable works pertaining to all departments of human knowledge.

"But this section cannot, by any fair construction of its language, be deemed to imply that any appropriation to that amount, or nearly so, was intended to be required. It is not a direction to the Regents to apply that sum, but a prohibition to apply more; and it leaves it to the Regents to decide what amount within the sum limited can be advantageously applied to the library, having a due regard to the other objects enumerated in the law.

"Indeed the eighth section would seem to be intended to prevent the absorption of the funds of the Institution in the purchase of books. And there would seem to be sound reason for giving it that construction; for such an application of the funds could hardly be regarded as a faithful execution of the trust; for the collection of an immense library at Washington would certainly not tend 'to increase or diffuse knowledge' in any other country, not even among the countrymen of the testator; very few even of the citizens of the United States would receive any benefit from it. And if the money was to be so appropriated, it would have been far better to buy the books and place them at once in the Congress library. They would be more acceptable to the public there, and it would have saved the expense of a costly building and the salaries of the officers; yet nobody would have listened to such a proposition, or consented that the United States should take to itself and for its own use the money which they accepted as a trust for 'the increase and diffusion of knowledge among men.'

"This is the construction which the Regents have given to the acts of Congress, and, in the opinion of the committee, it is the true one; and, acting under it, they have erected a commodious building, given their attention to all the branches of science mentioned in the law, to the full extent of the means afforded by the fund of the Institution, and have been forming a library of choice and valuable books, amounting already to more than fifteen thousand volumes. The books are, for the most part, precisely of the character calculated to carry out the intentions of the donor of the fund and of the act of Congress. They are chiefly composed of works published by or under the auspices of the numerous institutions of Europe which are engaged in scientific pursuits, giving an account of their respective researches and of new discoveries whenever they are made. These works are sent to the 'Smithsonian Institution,' in return for the publications of this Institution, which are transmitted to the learned societies and establishments abroad. The library thus formed, and the means by which it is accomplished, are peculiarly calculated to attain the object for which the munificent legacy was given in trust to the United States. The publication of the results of scientific researches made by the institution is calculated to stimulate American genius, and at the same time enable it to bring before the public the fruits of its labors. And the transmission of

these publications to the learned societies in Europe, and receiving in return the fruits of similar researches made by them, gives to each the benefit of the 'increase of knowledge' which either may obtain, and at the same time diffuses it throughout the civilized world. The library thus formed will contain books suitable to the present state of scientific knowledge, and will keep pace with its advance; and it is certainly far superior to a vast collection of expensive works, most of which may be found in any public library, and many of which are mere objects of curiosity or amusement, and seldom, if ever, opened by any one engaged in the pursuits of science.

"These operations appear to have been carried out by the Regents, under the immediate superintendence of Professor Henry, with zeal, energy, and discretion, and with the strictest regard to economy in the expenditure of the funds. Nor does there seem to be any other mode which Congress could prescribe or the Regents adopt which would better fulfil the high trust which the United States have undertaken to perform. No fixed and immutable plan prescribed by law or adopted by the Regents would attain the objects of the trust. It was evidently the intention of the donor that it should be carried into execution by an institution or establishment, as it is termed in his will. Congress has created one, and given it ample powers, but directing its attention particularly to the objects enumerated in the law; and it is the duty of that Institution to avail itself of the lights of experience, and to change its plan of operations when they are convinced that a different one will better accomplish the objects of the trust. The Regents have done so, and wisely, for the reasons above stated. The committee see nothing, therefore, in their conduct which calls for any new legislation or any change in the powers now exercised by the Regents.

"For many of the views and statements in the foregoing report the committee are indebted to the full and luminous reports of the Board of Regents. From the views entertained by the committee, after an impartial examination of the proceedings referred to, the committee have adopted the language of the resolution, 'that no action of the Senate is necessary and proper in regard to the Smithsonian Institution; *and this is the unanimous opinion of the committee.*'"

REPORT OF THE SECRETARY FOR 1856.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: The report of the operations of the year which has just closed may be considered as completing the first decade of the history of the establishment entrusted to your care. The act incorporating the Institution was approved by the President, August 20, 1846, and the first session of the Board of Regents was commenced on the 7th of the following September. It was, however, principally occupied in discussions relative to the plan of organization, which was not adopted until the beginning of 1847; and hence, although this report will be the eleventh, yet, in reality, it completes the account of but little more than the operations of ten years. It may therefore be proper, on the present occasion, to present in review a few of the prominent points in the history of the Institution.

In the beginning of an establishment of this kind, intended to last as long as the government of the United States shall endure, it was more important that every step should be in the proper direction, than that great advances should be made. The condition of an institution after a given time is to be estimated by what it has done well, rather than by the amount of what it has accomplished. Activity improperly directed is worse than inaction, and a wrong step at the commencement may produce effects which will be injuriously felt during the whole succeeding career.

From the outset there were many obstacles in the way of the proper establishment of this Institution. It was not clear to the minds of many that the general government had the power to accept a trust intended for the promotion of knowledge; and after this point was settled in the affirmative, a new difficulty arose in construing the will. The bequest was of so novel a character, and the terms in which it was expressed so brief, though precise, that much difference of opinion naturally prevailed as to the intention of the donor and the means of carrying it into execution. Another difficulty grew out of the manner

in which the funds were invested; and from these causes it was not until after a delay of eight years that the law which organized the Institution was enacted. Congress, it is true, intended in good faith to compensate for this delay by granting interest on the fund from the time the money was received into the treasury of the United States; but, unfortunately, the whole of this accrued interest, and as much of the annual income as might be thought necessary, were by the authority of law appropriated to a building of a magnitude incommensurate with the means or wants of the establishment. The administration of the trust was given in charge to a Board of Regents, whose special duty it was to study the character of the bequest with more attention than it had previously received. They were not, however, left entirely free to adopt such a plan as after mature deliberation they might think best fitted to carry out the intention of the donor, but were directed to include in the organization several objects which, in the opinion of a majority of the Board, were not in accordance with a strict interpretation of the will, or with the annual income of the bequest.

The founder of the Institution was a man of liberal education, a graduate of Oxford, an active member of the Royal Society, and devoted, during a long life, to original scientific research. Not content with the acquisition of ordinary learning, he sought by his own labors to enlarge the bounds of existing knowledge. Well acquainted with the precise meaning of words, while he left the mode of accomplishing his benevolent design to the trustees whom he had chosen, he specified definitely the object of his bequest. In consideration of his character, as evinced by his life, there can be no reasonable doubt that he intended by the terms "an establishment for the increase and diffusion of knowledge among men," an institution to promote the discovery of new truths, and the diffusion of these to every part of the civilized world. This view, however, was not at first entertained, and various plans, founded on misconceptions, were proposed for the organization of the Institution. The most prominent of these propositions were, first, to found a national university which should be supplementary to the colleges of the country; secondly, to diffuse popular information among the people of the United States by the distribution of tracts; thirdly, to establish at the seat of government a large library; and fourthly, a national museum. Though these propositions embraced objects of high importance in themselves, and probably affected the legislation of Congress, they did not embody the prominent ideas of the testator. They were restricted in their influ-

ence to this country, confined to a limited diffusion of existing knowledge, and made no provision for new discoveries.

Fortunately the Board of Regents, with more precise knowledge of the subject and with more liberal views, after much deliberation, were enabled to adopt a plan of organization, which, while it provided for the requirements of Congress, presented as its most prominent feature the promotion of original research in the various branches of science.

Although the directors have had to contend with popular misconceptions and with opposition from other sources in carrying out this plan, it has constantly been adhered to, and by its means a reputation has been established and an influence exerted in the line of the promotion of knowledge as wide as the civilized world. All the requirements of Congress have been strictly complied with, a building, making provision on a liberal scale for a library, a museum, a gallery of art, lectures, &c., has been erected at a cost of 325,000 dollars; and this sum, by prolonging the time of completing the building, has been paid entirely out of the interest. The whole amount of the original bequest, 515,000 dollars, remains untouched in the Treasury of the United States; and in order to assist in defraying the heavy annual expense of the support of the establishment necessarily connected with so large an edifice, the sum of 125,000 dollars has been saved from the income and added to the principal.

A library has been established, unrivaled in its series of the transactions of learned societies, and containing nearly 50,000 articles; a museum has been collected, the most extensive in the world, as regards the natural history of the North American continent; a cabinet of apparatus has been procured through the liberality of Dr. Hare, and other means sufficient to illustrate the principal phenomena of chemistry and natural philosophy, as well as to serve the purpose of original research; and an annual series of lectures have been given to large audiences by some of the most distinguished scientific and literary individuals in the United States.

Although economy and forethought have been observed in providing for these objects, they have absorbed a considerable portion of the income, and lessened the amount of good which might have been accomplished by a policy of a more truly cosmopolitan character. They have, however, as far as possible, been made subservient to the direct promotion of knowledge; and in this behalf, notwithstanding its limited means, the Institution has accomplished much that is important.

It has published a large series of original papers on the following branches of science, namely on

Mathematics and Physics	4
Astronomy	14
Meteorology	5
Chemistry and Technology	2
Geography, Ethnology and Philology	11
Microscopical Science	4
Zoology and Physiology	8
Botany	7
Palæontology	4
Geology	1
Miscellaneous	11
Making in all	71

Not only have these memoirs been published and distributed at the expense of the Institution, but the production of most of them has been facilitated by assistance rendered by its funds, its library, its collections, and its influence. They are not mere essays or compilations relative to previously known and established truths, intended to diffuse popular information among the people of the United States, but positive additions to the sum of human knowledge, presented in a form best fitted for the student and the teacher, and designed through them to improve the condition of man generally. Though in some cases they may appear to have no connexion with his wants, yet they are really essential to his mental, moral, or physical development. Every well established truth is an addition to the sum of human power, and though it may not find an immediate application to the economy of every day life, we may safely commit it to the stream of time, in the confident anticipation that the world will not fail to realize its beneficial results. We are assured, as we have said before, both from the example of Smithson himself, and from the words conveying the intention of his bequest, that the promotion of the discovery of such truths was his principal design in founding the Institution which is to perpetuate and honor his name. Copies of the published memoirs are sent to all the first-class libraries of the civilized world, and in this way the idea of "diffusion of knowledge among men" has been most effectually realized. Besides the memoirs referred to, a large number of important reports and miscellaneous papers have been published.

Natural history explorations have been made at the expense of the government, but principally at the instance and under the scientific direction of this Institution, which have done more to develop a knowledge of the peculiar character of the western portions of this continent than all previous researches on the subject. A system of exchange is now in successful operation, connecting in friendly relations the cultivators of literature and science in this country, with their brethren in every part of the Old World. A large amount of valuable material has been collected with regard to the meteorology of the North American continent, and a system of observations organized which, if properly conducted in future, will tend to establish a knowledge of the peculiarities of our climate, and to develope the laws of the storms which visit particularly the eastern portion of the United States during the winter. A series of original researches have been made in the Institution in regard to different branches of natural history, and also to portions of physical science particularly applicable to economical purposes.

In consideration of the difficulties with which the directors of the Institution have had to contend, it will, I think, be generally admitted that more has been accomplished than, under the circumstances, could have reasonably been anticipated. Although several steps may have been taken which were not in the proper direction, the Regents can scarcely be considered responsible for these, since they were not entirely free to choose their own course, but were obliged to be governed by the provisions of the act of incorporation.

Whatever ground of doubt may have existed as to the authority of Congress to accept the charge of the bequest, there can be none as to the obligation to carry out the intention of the testator now that the duty has been undertaken. The character of the government for justice and intelligence is involved in the faithful and proper discharge of the obligation assumed; and this becomes a matter of graver importance when it is considered that on the successful administration of the affairs of this Institution depends the bestowment of other legacies of a similar character intended for the good of men. If this Institution should prove a failure, the loss would not be confined to the money bequeathed by Smithson, but would involve the loss of confidence in the management by public bodies of like trusts committed to their care.

The adverse effects of the early and consequently imperfect legis-

lation ought, therefore, as far as possible, to be obviated; and this could readily be done, if Congress would relieve the Institution from the care of a large collection of specimens principally belonging to the government, and purchase the building to be used as a depository of all the objects of natural history and the fine arts belonging to the nation. If this were done, a few rooms would be sufficient for transacting the business of the Institution, and a larger portion of the income would be free to be applied to the more immediate objects of the bequest. Indeed, it would be a gain to science could the Institution give away the building for no other consideration than that of being relieved from the costly charge of the collections; and, for the present, it may be well to adopt the plan suggested in a late report of the Commissioner of Patents, namely, to remove the museum of the Exploring Expedition, which now fills a large and valuable room in the Patent Office, wanted for the exhibition of models, to the spacious hall of the Institution, at present unoccupied, and to continue under the direction of the Regents, the appropriation now annually made for the preservation and display of the collections.

Although the Regents, a few years ago, declined to accept this museum as a gift, yet, since experience has shown that the building will ultimately be filled with objects of natural history belonging to the general government, which, for the good of science, it will be necessary to preserve, it may be a question whether, in consideration of this fact, it would not be well to offer the use of the large room immediately for a national museum, of which the Smithsonian Institution would be the mere curator, and the expense of maintaining which should be paid by the general government. The cost of keeping the museum of the Exploring Expedition, now in the Patent Office, including heating, pay of watchmen, &c., is about $5,000, and if the plan proposed is adopted, the Institution and the Patent Office will both be benefitted. The burden which is now thrown on the Institution, of preserving the specimens which have been collected by the different expeditions instituted by government during the last ten years, will be at least in part removed, and the Patent Office will acquire the occupancy of one of the largest rooms in its building for the legitimate purposes of its establishment. It is believed that the benefit from this plan is so obvious that no objection to it would be made in Congress, and that it would meet the approbation of the public generally.

Nothing has occurred during the past year to vary the character of the financial statement which has been given in previous reports. By a reference to the report of the Building Committee, it will be seen that a final settlement has been made with the contractor, and, from the statements of the Executive Committee, that $120,000 have been invested in State stocks, bearing an annual interest of $7,830, and that there is also in the hands of the Treasurer $5,000 to be invested.

During the present year the income from the extra fund can, for the first time, be appropriated, at least in part, to other purposes than the building. The repairs, however, the cases and furniture required for the care of the collections, together with the lighting and heating, the pay of the watchman and laborers rendered necessary by so large an establishment, will consume a considerable portion of the income from this source. The expenditure on these items will tend to increase rather than diminish with time, and therefore it will be prudent to confine the appropriations considerably within the income, in order to meet unforeseen demands.

No especial appropriation has yet been made by Congress for continuing the improvement of the grounds; and it is to be regretted that years should be suffered to pass without planting the trees which are in the future to add to the beauty, health, and comfort of the metropolis of the nation. Unjust censure is frequently bestowed on the Institution on account of the neglected condition of these grounds, over which it has no control, and on which it would manifestly be improper to expend any of its funds. No part of the public domain is more used than the reservation on which the building stands, and I doubt not, if the matter were properly brought before Congress, an appropriation for the immediate supply of trees and its general improvement would be granted.

During the past year a beautiful monument has been erected near the Institution by the American Pomological Society, to the memory of the lamented Downing. It is a just tribute to the worth of one of the benefactors of our country, and affords an interesting addition to the ornamental plan furnished by himself for the public parks of this city. The adoption of this plan is in part due to the efforts of the Regents in the way of embellishing the grounds around the Smithsonian building.

Publications.—The eighth annual quarto volume of Contributions to Knowledge has been printed and distributed. It contains the following memoirs:

Archæology of the United States, or Sketches, Historical and Bibliographical, of the progress of information and opinion respecting vestiges of antiquity in the United States, by Samuel F. Haven, Esq.

On the recent Secular Period of the Aurora Borealis, by Denison Olmsted, L.L.D.

The Tangencies of Circles and of Spheres, by Major Benjamin Alvord, U. S. A.

Researches, Chemical and Physiological, concerning certain North American Vertebrata, by Joseph Jones, M.D.

Record of Auroral Phenomena, observed in the higher northern latitudes, by Peter Force, Esq.

List of the transactions of learned societies in the library of the Smithsonian Institution.

An account has been given of all the articles published in the 8th volume, with the exception of the paper of Dr. Jones. The investigations recorded in this memoir were made by an under graduate of the medical department of the University of Pennsylvania, and were accepted for publication on the authority of Professors Jackson and Leidy of that institution. The experiments were made on alligators, terrapins, reptiles, fishes, and other animals. They were necessarily attended with much labor and many embarrassments, on account of the peculiar habits of the animals on which they were made, and the difficulty of access to, and the miasmatic condition of, the localities whence the specimens were obtained. The investigations were, for the most part, conducted in Liberty county, Georgia, where the author had an opportunity of obtaining fresh specimens of vertebrate animals seldom enjoyed by previous observers; and the industry and zeal which he has exhibited in prosecuting his researches are highly commendable, particularly in the case of an under graduate of one of our medical universities.

The memoir is divided into a series of chapters, the first and second of which relate to the analysis of the blood of animals in the normal condition; the third and fourth to the physical and chemical changes in the solids and fluids of animals when deprived of food and drink, and also the effects of a change of diet. The remaining chapters present a series of observations upon the alimentary canal, the comparative anatomy and physiology of the pancreas, liver, spleen, the kidneys, and the urine. The following are among the conclusions arrived

at by the author; and though some of them may have been previously obtained, yet they will serve even in these cases to verify the results of other investigations.

The amount of water in the blood is greatest in the invertebrata. Among vertebrate animals it is greatest in fishes and aquatic reptiles, and least in serpents, birds, and mammals. It would appear, as a general law, that as the organs of the animal are developed, and the temperature and intellect correspondingly increased, the blood becomes richer in organic constituents. The blood of serpents, at first sight, appears to form an exception to this conclusion; the larger amount of solid matter existing in their blood is, however, accounted for by the fact that they seldom or never drink water, and as they are constantly, though slowly, evaporating this fluid, the blood must necessarily become concentrated and yield a larger quantity of solid constituents upon analysis. The proportion of the constituents of the blood of mammalia varies as much in individuals of the same species as in those of remotely separated genera. In the invertebrate animals the number of blood corpuscles is very small in comparison with that in the vertebrata. The fibrine constitutes a remarkable index of the vital, organic, and intellectual endowments of animals. In the whole of the invertebrate kingdom it is absent, except in a few of the most highly organized. In the lower order of the vertebrata, as fishes and batrachians, it is soft, unstable, and readily converted into albumen. The proportion of fixed saline constituents in the blood is remarkably uniform throughout the whole animal kingdom. Among the vertebrate animals the greatest amount of mineral constituents is found in fishes and reptiles inhabiting the salt water. In every instance during abstinence from nourishment, the water of the blood diminishes more rapidly than the solid portions. The rapidity of the consumption of the watery element, and the consequent concentration of blood, is connected with the vital and physical condition of the animal, being more rapid in the case of those of warm blood. The corpuscles waste during starvation, as well as the other components, thus proving that they have an important office to fulfil in the support of the tissues and organs of the living animal. The fibrine relatively increases during starvation and thirst. The fat of the body wastes more rapidly than any other of the tissues. The continuance of life of the animal during starvation and thirst is inversely proportional to the rapidity of change of its elements, and, as a necessary consequence, to its temperature and organic development. The relative weight of the heart to that of the body was found proportionably smaller in fishes

and larger in birds than in other animals. The blood lost during starvation was rapidly restored with vegetable diet, its solid constituents, however, were less with the latter than with animal food. The proportion between the blood corpuscles and liquor sanguinis was not altered, though the saline constituents were diminished with a vegetable diet. In many instances the shells of the terrapins became softer, and the effect of a change of diet was also exhibited in the digestive organs. The small intestines were enlarged, and a much greater amount of water was thrown into the circulation than in the case of the use of animal food, and hence water, holding albumen in solution, accumulated in the cellular tissues and serous cavities. The urine was rendered more abundant, and its specific gravity and chemical relations changed.

The remarkable difference which is known to exist between the digestive apparatus of carnivorous and graminivorous animals, is exhibited most strikingly in the comparative length of the alimentary canal; for example, that of the common cat is five feet and a third in length, while that of the sheep is eighty-eight feet.

Fishes afford the best means of studying the development of the pancreas; the permanent forms which it assumes in them being but the transient condition of its development during the growth of the higher animals. This organ is found in carnivorous fishes, reptiles, and mammalia, to be relatively much larger than in frugivorous and graminivorous animals. The pancreas of warm-blooded is larger than that of cold-blooded carnivora. The opinion advanced by Bernard is sustained, viz: that the office of the pancreas is to prepare fatty matter for absorption. The shape and appearance of the liver vary greatly. The former appears to be determined by that of the animal and its abdominal cavity. The size also varies, and on this point a series of results are given as to the ratio of its weight to that of the whole body. The livers of all animals, cold or warm-blooded, as far as the author's observations have extended, yield grape sugar, which passes into the circulation and disappears in the lungs so long as normal respiration is maintained. In cold-blooded animals it is never a healthy constituent of the urine; if a supply of oxygen be cut off, it is accumulated in the blood and eliminated by the kidneys. The spleen, which is absent from all invertebrate animals, varies in form, size, and position in different reptiles. In the mammalia it is large, and presents manifold diversities of form. It is smallest in birds and ophidians, and largest in fishes and mammals. It appears to be an

organ of subordinate importance in the animal economy, and of its real office the anatomist is still ignorant. Its function is not indispensable to the maintenance of life.

The kidneys are excreting and not secreting organs; and the amount and character of the excretions depend upon certain materials in the blood. When the kidneys are excised, other membranes and organs assume their office; and it is probable that in lower animals, which are without this organ, its functions are performed by the mucous membrane of the stomach and intestines. As far as the observations of the author extend, the kidneys are larger in carnivorous than in other animals. The urine of fishes is difficult to be obtained, the bladders are almost always empty. The amount of urine excreted by a warm-blooded animal is from forty to several hundred times that furnished by a cold-blooded animal.

From this very brief exposition of the results obtained some idea may be formed of the amount of labor bestowed on these investigations; and whatever estimate may be formed of the speculations of the author, there can be but one opinion as to the value of the facts which he presents.

The next article accepted since the date of the last report, and which has been printed and partially distributed, will form a part of the 9th volume. It is by J. D. Runkle, and is entitled, "New tables for determining the values of the co-efficients in the perturbative function of planetary motions which depend upon the ratio of the mean distances." The object of these tables is to facilitate the calculation of the places of the planets, and other astronomical researches.

In determining the mutual action of any two planets in our solar system, there are certain quantities, depending upon the ratio of the mean distances of these bodies from the sun, which must first be computed. The number of these quantities, and the labor necessary to compute each one of them, makes this first step in the reduction of the mutual action of the two planets to numbers, a serious work. But when it is remembered that there are fifty planets already known, and that others, especially among the asteroid group, are probably still to be discovered, the desirableness of determining all these quantities by some short and easy process cannot admit of question. The tables just published by the Institution accomplish this desired end with the greatest possible facility. Their use gives the same advantage in the calculations to which they are applied that a table of logarithms affords in arithmetical operations. The tedious labor of

computing these quantities for the old planets has already been performed three or four times over—a labor which these tables would have saved, and will save in the future for all the planets whose mean distances are not at present sufficiently well known. The supplement to the tables contains the qualities necessary in the computation of the mutual perturbations of the eight principal planets ; and the supplement continued, which will be published during the present year, will contain the quantities which correspond to the asteroids. In order to ensure accuracy in printing these tables, they have been stereotyped. The work was referred to Prof. B. Peirce, of Harvard University, and Capt. C. H. Davis, Superintendent of the American Nautical Almanac, and it is published on their recommendation.

Another paper which has been accepted for publication, and is now ready for distribution, is by Prof. Wolcott Gibbs, of New York, and Dr. F. A. Genth, of Philadelphia, entitled "Researches on the Ammonia-cobalt bases." It consists of a laborious series of investigations relative to a very interesting part of chemistry. This memoir is chiefly important from a theoretical point of view, though it will probably be found to possess many important practical applications. Chemists have long recognized the existence of a class of bodies called bases, which possess the property of neutralizing acids, and of forming with them what are commonly called salts. These bases are usually oxides of metals, or of substances which play in combination the part of metals. Thus the protoxide and sesquioxide of iron are in this sense simple bases, while quinine, morphine, strychnine, &c., form examples of complex bases, or oxides of what chemists term compound radicals. It usually happens that metals which belong to the same natural family or group form oxides which have an analogous constitution. Thus iron, manganese, chromium, cobalt, and nickel all form sesquioxides as well as protoxides. The protoxides of these metals are strong bases. The sesquioxides of chromium, iron, and manganese are also bases, while those of cobalt and nickel rarely, if ever, exhibit basic properties. Under these circumstances, it is very interesting to find that the union of the sesquioxide of cobalt with a few equivalents of ammonia, or of ammonia and deutoxide of nitrogen, confers upon it the property of forming stable combinations with acids, or, in other words, *salts*. In the memoir referred to, four distinct classes of such compound bases are described. Of these, two are entirely new, while the others had, up to this time, been very imperfectly investigated.

The bases described in the memoir are termed conjugate, from the

fact that they contain substances in a manner yoked together. Such compounds are not altogether new, and chemists have long assumed or admitted the existence of both conjugate acids and bases. In its most general form, the idea of a conjugate body implies that two or more substances are united in such a way that the properties of one or two of these substances are lost or become insensible, while those of another are more or less essentially modified. Thus the body A may either increase or diminish the acid or basic properties of the body B, but its own properties are at the same time lost, or at least do not appear in those of the compound. The ammonia-cobalt bases furnish the best defined and most instructive class of conjugate bodies yet discovered, and have abundantly repaid the very great labor which has been bestowed upon them. It can scarcely be doubted that their study will give an impulse to chemical science, and will be followed by that of other bodies of the same character. The remarkably beautiful and brilliant colors which many of these compounds exhibit lead to the hope that some, at least, may find direct practical applications in dyeing. Drs. Gibbs and Genth propose to continue their researches, and to present the fruits of an extended study in a second part of their memoir.

This paper is illustrated by a number of wood engravings of the forms of the crystals, drawn under the direction of Prof. Dana, to whom the authors are indebted for the determination of the systems to which many of the crystals belong, and of their principal forms. They have also been furnished with facilities in the line of their researches from the Smithsonian fund, which renders it proper that the results should first appear in the "Contributions" of the Institution, although the paper will probably be republished in some of the scientific periodicals of the day.

In the reports for 1850 and 1852, accounts are given of a work prepared for the Smithsonian Institution by Professor Harvey, of the University of Dublin, on the Algæ found along the eastern and southern coasts of the United States. Two parts of this work have been published, and have received the approbation of the scientific world.

In reference to the first part, I may be allowed to quote the following remarks of the late Professor Forbes, of Edinburgh, than whom no better authority could be cited:

"Professor Harvey is one of the ablest and most philosophical of living botanists. His fame with the multitude is, however, very small compared with the honor assigned to him by his scientific

peers. * * * A more proper person than Professor Harvey could not have been selected for the elaboration of a 'Nereis Boreali-Americana,' and most honorable is it to the directors of the Smithsonian Institution of North America that they should have selected this gentleman for the task of which we have now the first fruits. The trustees of that establishment are pursuing a course which is sure to do much towards the wholesome development of science in the United States. In the present instance they have done what is both wise and generous, and, in seeking the best man to do the difficult work they require done, have recognized nobly the truth that science belongs to the world, to all mankind, laboring for the benefit of all regions and races alike."

Professor Harvey has lately returned from an exploration around the shores of the Pacific ocean, and has promised to complete the third part of the work during the present year. It will include an account of the Algæ along the coasts of Oregon and California. The labors of the author, including the drawings of the plants on the stone, are entirely gratuitous; yet the publication of the work is very expensive, and it is proposed to lessen the cost to the Institution by striking off a number of extra copies for sale to individuals. This may be done without risk, since a growing taste is manifested in the study of this interesting branch of botany, and a number of copies have already been ordered by booksellers.

The three papers mentioned in the report for 1855, on surface geology, by Professor Hitchcock, are now in the press. By a reduction in the size, and a re-arrangement of the plates under the superintendence of Professor Baird, the cost of the publication of these communications will be much diminished. The plates require to be colored, and the reduction of expense, as well as an increased beauty of effect, is produced by adopting the chromo-lithographic process. The author proposes to apply to the legislature of Massachusetts for an appropriation to purchase copies of this work as a supplement to his report on the geology of that State.

Since the last meeting of the Board, the paper previously mentioned on the "Relative Intensity of the Heat and Light of the Sun, by L. W. Meech," has been published and partially distributed. The following propositions are discussed in this memoir, viz: The proportion of a planet's surface which is irradiated by the sun at a given time, as deduced from the relative size and distance of the two bodies. The sun's intensity upon the planets in relation to their orbits. The

law of the sun's intensity at any instant during the day. Determination of the sun's hourly and diurnal intensity. On local and climatic changes of the sun's intensity. On the diurnal and annual duration of sunlight and twilight. These are all mathematical deductions from well established principles, and constitute the preliminary problems towards a logical solution of the phenomena of the meteorology of our earth. The author offers to continue his interesting investigations in this line of research, provided the Institution will employ a person to make the arithmetical calculations, or, in other words, to deduce from the formulæ the numerical values of the quantities required. His own time must be principally occupied in other duties, though he will cheerfully devote his leisure hours to the investigations, with a view of extending the bounds of knowledge. He considers most of the memoirs which have been published in the transactions of different learned societies as preparatory to a more complete solution of the problem of terrestrial heat. He has succeeded in bringing the formulæ of the theory of heat in closer connexion with observation than heretofore, and thinks there is now an opportunity presented for increasing our knowledge of meteorology on the "theoretic side." From a consideration of the interesting problems which have been discussed in the memoir just published, and the manner of their solution, it can scarcely be doubted that valuable results will be produced by an appropriation for the continuance of these researches.

The first part of the paper on Oōlogy, described in the last report, is now in the hands of the printer. Every possible pains has been taken to make the illustrations as accurate representations of the objects as can be accomplished by art. The globular shape of the eggs, and the receding aspect of their markings, have heretofore baffled all endeavors to represent them correctly. The best and most artistic works of this kind, involving a very expensive operation, are but partially successful. The desideratum has been obtained by the employment of photography in making the original delineations, and this has furnished an exact and available basis, which the engraver can copy at his leisure, and which represents with fidelity, otherwise unattainable, the appearance to be perpetuated. These improvements have been made by Mr. L. H. Bradford, of Boston, to whom the engraving has been entrusted. The plates will be printed in colors. An order has been received from England, in advance, for a number of copies of this work, the proceeds of which will be devoted to lessening the cost of the illustrations.

The publication of the paper mentioned in the report for 1854, relative to the Zapotec remains in Mitla, Mexico, was delayed on account of the absence of Mr. Brantz Mayer, who undertook to prepare an account of the drawings made by Mr. Sawkins, with general observations on Mexican history and archæology. It has, however, been published since the date of the last report, and will form a part of the ninth volume of the contributions. It was referred to Mr. Haven, of the Antiquarian Society, Worcester, Massachusetts, and to Dr. E. H. Davis, of New York. This paper, as well as that of Mr. Haven on the archæology of the United States, possesses much more popular interest than many of the Contributions published by the Institutions, and is therefore in greater demand.

Reports on Progress of Knowledge.—One of the propositions embraced in the plan of organization is the publication of reports on the progress of knowledge; but the portion of the fund which could be expended in printing has been so much more advantageously employed in giving to the world memoirs consisting of original contributions to science, that but little has been done in regard to this part of the original plan. It has not, however, been entirely neglected. Besides the work of Messrs. Booth and Morfit on the progress of the Chemical Arts, the last annual report of the Regents to Congress contains an account of late researches relative to Electricity. Another part of the same work will be given in an appendix to this report.

The report on forest trees by Dr. Gray, of Cambridge, is still in progress, but has been delayed principally on account of the more pressing engagements of the author in preparing his description of plants collected by different expeditions undertaken by the government, and in part from the difficulty of obtaining the necessary drawings for its illustration. Some of these can only be made at particular seasons of the year, during fructification, and other periods of the different phases of the parts of the trees. A sufficient number of the drawings have been prepared to form a considerable portion of the work; but as these in many cases belong to different genera, they cannot properly be published until the others are prepared, which are necessary to complete definite series. Nevertheless, it is expected that the first part of the work will be ready for the press during this year. Instead, however, of presenting it in the form of a report, it has been thought advisable to publish it as a part of the quarto series of original Contributions to Knowledge. For, though the facts it contains are not entirely new, the work will in no sense be a compi-

lation; the drawings and descriptions will all be original, and it will probably contain a series of experiments and observations on the economical uses of our trees, which have never before been published. Besides this, the quarto form is best adapted for the illustrations.

The Report on education, mentioned at the last meeting of the Board as in progress of preparation by the Hon. Henry Barnard, of Connecticut, has not yet been completed. We hope, however, to be able to obtain the article during the present year, and to give it to the public either as an appendix to the annual report or in a separate form.

The printing of the second and enlarged edition of the *Meteorological and physical tables*, which was announced in the last report as having been commenced, has been delayed on account of an error detected by the author in the reduction of one of the formulas, which required the recomputation of a considerable number of pages. We regret that much disappointment has been felt at the long delay of the appearance of these tables, which has been owing to the many pressing engagements of the author. We have now directed the printer to strike off such portions of the work as are stereotyped, and these will probably be ready for distribution to our meteorological observers before the publication of this report.

These tables will serve to form a part of a great work suggested by Mr. Babbage, entitled "The Constants of Nature and Art," intended to contain all facts which can be expressed in numbers, in the various branches of knowledge, such as the atomic weights of bodies, specific gravities, elasticity, tenacity, specific heat, conducting power, melting point; weight of different gases, liquids, and solids; the strength of different materials; velocity of sound of cannon balls; electricity, light, animals, &c., &c., &c. Such a work would be perpetually useful in original investigations, as well as in the application of science to the useful arts; but to carry out fully the idea of the author, the co-operation of a number of institutions would be necessary. It, however, consists of parts, any one of which will be considered of immediate value. An account and examples of this work are given in the appendix.

The materials for a new edition of the *Report on Libraries* have been collected, and are now being arranged and prepared for the press by Mr. Rhees, chief clerk of the Institution. Considerable difficulty has been experienced in obtaining answers to the circulars first issued, but the distribution of a second edition has called forth a large amount

of interesting information. The work will exhibit the rapid progress which this country is making in the means of acquiring knowledge, as well as indicate the kind of books which receive most attention. It was at first proposed to publish it as a part of the appendix of the Report to Congress; but it has been found impossible to complete it in time for that purpose, and it will, therefore, be printed by the Institution in a separate form.

Exchanges.—The system of international exchanges has been carried on during the year 1856 with unabated activity, but with increasing expense, notwithstanding the liberal assistance which has been continued by the several transportation companies mentioned in the last report. A large room, occupying nearly the whole of the first floor of the east wing, 75 feet long and upwards of 30 feet in width, has been devoted entirely to the business connected with the exchanges. It has been fitted up with cases, shelves, and boxes, similar in arrangement to a post office, in which a separate space is appropriated to each country and each institution.

This part of the general operations of the Institution continues to be received with much favor by literary and scientific societies and individuals in this country and abroad, and is increasing every year in extent and usefulness. We hope, however, hereafter to render it more perfect and useful, particularly by increasing the frequency of transmissions.

I regret that at this time I am not able to give the exact statistics of the amount sent and received during the past year, since a second invoice is now in the course of preparation, containing many articles which should properly be included among those of the present year.

Meteorology.—In the last report of the Board of Regents it was announced that an arrangement had been made with the Commissioner of Patents by which the system of meteorology, established under the direction of the Institution, would be extended, and the results published more fully than could be done by the Smithsonian income alone; that a new set of blank forms had been prepared by myself, and widely distributed under the frank of the Patent Office; and also that an appropriation had been made for the purchase of a large number of rain-gauges, to be presented to observers in different parts of the country. This copartnership, as it may be called, has produced good results; the number of observers has increased, and the character of the instruments and of the observations has been

improved. The reduction of the registers has been continued by Prof. Coffin during the past year. He has completed those for 1854 and 1855, and is now engaged on those for 1856. A summary of the more important reductions for 1854 and 1855 was given in the last Report of the Patent Office, and hope was entertained that an arrangement could be made by which the whole series would be published at the expense of the general government. But this expectation has not been realized, and the Institution has commenced to stereotype the work on its own account. Copies of the stereotype impressions will be forwarded, from time to time, to observers, as they become ready for distribution.

During the past year many additions have been made to the number of observers, and increased interest has been awakened in the subject of meteorology. Quite a number of observers have furnished themselves with full sets of standard instruments, and the system has thus been increased in precision as well as magnitude. It is to be regretted, however, that the observers are not more uniformly distributed over the whole country; while the northern and eastern States are abundantly supplied the southern and western are deficient, particularly Indiana, Kentucky, Tennessee, Mississippi, Arkansas, Louisiana, and Texas.

Several of the observers publish the results of their observations in the newspapers of their vicinity, and we would commend this custom to general adoption. It serves to direct attention to the importance of precise records of the weather, to awaken a greater public interest in the subject of meteorology, and to gratify a laudable curiosity in the comparison of the variations of the different seasons. We would also recommend to the observers generally the plan adopted by some of them, of the construction of diagrams, exhibiting to the eye, at a single glance, the peculiarities of temperature, moisture, and direction of the wind, for different seasons and years.

All the materials possessed by the Institution relative to the direction and force of the wind, derived either from its own system or found in works received by exchange, have been placed in the hands of Prof. Coffin, to enable him to prepare a supplement to his valuable memoir on the "Winds of the Northern Hemisphere." This work requires a large amount of laborious arithmetical calculation, to defray the expense of a part of which a small sum has been granted from the appropriation for meteorology. The fact was also mentioned in the last report, that a valuable series of observations made in Texas and Mexico, by the late Dr. Berlandier, was placed at our disposition

by Lieutenant Couch, late of the United States army; and I am happy to state to the Board that these observations are at present in the process of revision, and that they will be published, at least in part, if not entirely, during the next year. The Institution is now also prepared to publish a number of series of observations continued for considerable periods of time, which will be of importance in the comparison of the weather of different years.

The great object in view in regard to this branch of science is to furnish materials which all who are so disposed may study, and from which deductions may be made as to the peculiarities of our climate, or the general meteorological phenomena of the globe. It is highly desirable that as many minds as possible should be employed on this subject, and it is consequently important that the greatest procurable amount of authentic data should be furnished to them as the basis of their investigations. The continent of North America presents a field of peculiar interest in regard to geography, geology, botany, zoology, and meteorology, which has been cultivated more industriously since the establishment of this Institution than at any former period; and now, with the proper co-operation of the medical department of the army, by means of observations made at the different military posts on the west, the system about to be established in Canada on the north, and that of the Smithsonian and Patent Office on the east, with that of the National Observatory on the sea surrounding our coast, more extended and accurate means than were ever before in existence will be offered for the solution of some of the most interesting problems of climatology. In order, however, to full success in this enterprise, all considerations of personal or institutional aggrandizement should be entirely discarded, and each party be impelled alone by the desire to advance as much as is in its power the cause of truth. The policy of this institution has ever been of a character as liberal as its means would permit, and we trust it will not cease to extend a generous co-operation to every well devised plan intended to promote knowledge.

We cannot hold out the idea that great results are at once to be obtained for the improvement of agriculture, and the promotion of health and comfort, by a system of meteorological investigation. There are no royal roads to knowledge, and we can only advance to new and important truths along the rugged path of experience, guided by cautious induction. We cannot promise to the farmer any great reduction in the time of the growth of his crops, or the means of pre-

dicting, with unerring certainty, the approach of storms. But in the course of a number of years the average character of the climate of the different parts of the country may be ascertained, and the data furnished for reducing to certainty, on the principle of insurance, what plants can be most profitably cultivated in a particular place; and it is highly probable that the laws of storms may be so far determined that we shall be able, when informed by the telegraph that one has commenced in any part of the country, to say how it will spread, and whether it may be expected to extend to our own locality. We make these remarks in order to prevent disappointment and the evils produced by exciting expectations which cannot possibly be realized.

Terrestrial Magnetism.—Nearly a continuous record of the changes of magnetic declination has been kept up by the photographic method, during the greater part of the past year, at the magnetic observatory established by the Institution and the United States Coast Survey. The series was interrupted, in December, by some improvements in the arrangement of the building, and by preparations for the mounting of additional instruments for recording the changes of horizontal and vertical force. The apparatus was constructed, at the request of Professor Bache, under the direction of Charles Brooke, Esq., of London, who originally designed this method of registration, and who kindly undertook to adjust all the delicate compensations. Similar instruments are in operation at the magnetic observatories of Greenwich, Paris and Toronto; and it is hoped that a continuous corresponding record will in future be made here, which will prove of great interest and utility in the study of the phenomena of terrestrial magnetism.

The set of portable magnetic instruments for absolute determinations belonging to the Institution are placed in charge of Baron Muller, who is making a scientific expedition to Mexico and Central America. Recent investigations having shown that magnetic observations in those regions, where none have been made since Humboldt visited them, more than fifty years ago, would have a special value in determining the law of distribution, the Institution availed itself of the opportunity offered by Baron Muller's expedition, to forward this branch of knowledge by furnishing instruments, and appropriating an amount adequate to cover the additional expenses occasioned by these observations. Full copies of the records are transmitted to the Institution as opportunity offers. The results of the observations, as far as

received, are given in the appendix to this report; they will be published in detail when the series is complete.

Laboratory.—It was stated in the last report that, in conformity with the act of Congress incorporating the Institution, a laboratory had been fitted up with the necessary appliances for original research in chemistry and other branches of physical science. During the past year, besides the examination of minerals and other substances submitted to the Institution, a series of experiments have been made relative to the strength of materials for building purposes, to some points of meteorology, and to electrical induction. The results that have been obtained from these investigations will, in due time, be given to the public.

Library.—During the past year the library has received, by exchange, a larger accession than during any previous year. The whole number of volumes, parts of volumes, and other articles obtained by this means, is 5,361.

The series of transactions and scientific periodicals is gradually becoming more and more complete; and, in the course of a few years, this collection will be as extensive as any to be found in the Old World. A second part of the catalogue of transactions, now in the library, has been published, and distributed to foreign institutions. In this the deficiencies of the library are pointed out, and in many cases these have already been supplied by the liberality of the societies having duplicates of the desired articles.

Though the books received by donation and exchange are of the most valuable character, and such as cannot, in many cases, be procured by purchase, yet, as they are generally presented in parts of volumes in paper covers, they require a large expenditure for binding. During the last two years, the sum of three thousand dollars has been paid for this purpose.

Among the liberal donors to whom the Smithsonian Library is indebted, principally on account of the system of exchange, special acknowledgment is due to the Prussian government for the continuation of the celebrated work, by Lepsius, on Egypt; to Baron Korff, of the Imperial library of Russia, for the volumes of the monuments of the Cimmerian Bosphorus; to the Board of Health of London, for a full set of its reports; to the Imperial Society of Naturalists of Moscow, for 21 volumes, 8vo, of the Bulletin of its proceedings; to F. A. Brockhaus, of Leipsic, for 151 quarto volumes of the Encyclopadie der Wissenschaften; to Justus Perthes, of Gotha, for ninety-

two volumes of maps and other geographical publications; to R. Lepsius, for a nearly complete series of his philological and ethnological works; to the Naturforschende Gesellschaft, at Basle, for seventy-three volumes of rare scientific journals; to the Geological Society of France, for eleven volumes of its Bulletin, and four volumes of its Memoirs; to the Observatory at Milan, for fifteen volumes of Effemeridi; to the University of Athens, for thirty-four volumes of modern Greek works; to the University of Tubingen, for twenty-eight folio and quarto volumes of rare and curious incunabula; to the Riks-bibliotek of Stockholm, for three hundred volumes of proceedings of the Swedish Diet; to the London Admiralty, for ninety charts, published from August, 1855, to August, 1856; to Dr. Thomas B. Wilson, of Philadelphia, for a set of Buffon's works, 28 volumes, and Nouveau Dictionnaire d'Historie Naturelle, 30 volumes; to the Duke de Lugnes, for a fac-simile of the inscription on the Sidonian sarcophagus, and the volume describing it, which were furnished at the request of the Institution, for the use of some of our oriental scholars, by its liberal author.

In regard to the last mentioned donation the following account may, perhaps, be interesting: A sarcophagus, bearing a long Phœnician inscription, having been exhumed in the vicinity of the ancient Sidon, in the beginning of the year 1855, the American missionaries on the spot, with praiseworthy zeal for learning, took copies of the writing and transmitted them to this country and to Europe, and scholars on both sides of the water immediately entered upon its study and gave their interpretations to the world. Meanwhile, the sarcophagus itself was purchased by the Duc de Lugnes and presented to the French government, who deposited it in the gallery of the Louvre. It had become evident that the copies of the inscription on which the first interpretation was based, owing to the imperfect means at command, were necessarily, in several respects, unreliable. At the request of Prof. E. E. Salisbury, of Yale College, and William W. Turner, Librarian of the Patent Office, who had chiefly occupied themselves with the study of the monument in this country, application was made to the Duc de Lugnes, who, with generous promptness, presented to the Institution exceedingly well executed *fac-similes* of the inscriptions on the lid and on the sides of the sarcophagus, and a copy of the work illustrating the same, published by himself for private distribution. Thus American scholars are afforded the same opportunity as is possessed by their compeers in Europe of making

an independent study, with authentic materials, of this highly interesting relic of antiquity.

We have frequently stated that the principal object of the library is to furnish the colaborators of the Institution with the means of ascertaining what has been accomplished in the particular line of their research. For this purpose, under certain restrictions, we have forwarded books to different parts of the country, and this we are enabled to do, without much risk of loss, by means of the system of express agency which now forms a net-work of intercommunication over all parts of the United States. A volume may, it is true, be occasionally lost; but it is better to hazard an occurrence of this kind than that the books should not be used. The library is also consulted by the officers of the army, the navy, of the Coast Survey, and the men of science who have been connected with the several exploring expeditions; and in this way, it has been made to subserve the general object of the Institution in the promotion of knowledge. The expense of this part, however, of the operations of the library is small, in comparison with that which is in reality of little importance. I allude to the cost of keeping up a reading-room, in which the light publications of the day, obtained through the copyright law, are perused principally by young persons. Although the law requiring a copy of each book for which a copyright is granted, to be deposited in the library was intended to benefit the Institution, and would do so were it designed to establish a general miscellaneous collection, yet as this is not the case, and as some of the principal publishers do not regard the law, the enactment has proved an injury rather than a benefit. The articles received are principally elementary school manuals and the ephemeral productions of the teeming press, including labels for patent medicines, perfumery, and sheets of popular music. The cost of postage, clerk-hire, certificates, shelf-room, &c., of these far exceeds the value of the good works received. Indeed, all the books published in the United States, which might be required for the library, could have been purchased for one-tenth of what has been expended on those obtained by the copyright law. Similar complaints are made by the Library of Congress and the Department of State; and it is therefore evident that this subject requires the attention of government. Three copies of every work are now required to be sent to Washington, but in no one of these cases is the intention of the copyright law fully carried out. If the books are to be preserved as evidence of title it would seem most fit that they should be deposited

and preserved in the Patent Office with other samples of the protected products of original thought, namely: models of invention and specimens of design.

Two double cases, each fifty feet in length, have been provided during the present year, which, with the previous shelves, will be sufficient to hold the books at present in the library and those which may be received for some time to come.

Museum.—It has been stated in previous reports that it is not the design of the Institution to form a general museum of all objects of natural history, but of such as are of a more immediate interest in advancing definite branches of physical research; and in view of this, special attention has been bestowed on developing the peculiarities of the productions of the American continent, with a view to ascertain what changes animals and plants have undergone, how they differ in their present as well as their past forms from those on other portions of the globe, and also the distribution of the same species, and the relations which they bear to the soil and climate where they are found. The great object of studies of this class is to determine the laws of the production, growth, and existence of living beings. The nature of life itself is at present unknown to us, except in its relation to certain organic forms and changes going on in them. It is, to our apprehension, inseparably connected in this world with transformations of bodies chemically composed of a few elementary materials, which are constantly being combined and decomposed, in accordance with laws peculiar to the living being. In reference to the forms which these materials assume, the whole animal kingdom has been referred to four great types or plans of structure, the Vertebrata, the Articulata, the Mollusca, and the Radiata. From these four types all the varieties that are found on the surface of the earth are derived. It appears to be a principle of nature that the most diversified effects are made to follow from a single conception, a fact which is well expressed by the terms "multiplicity in unity." Whilst every part of the earth is peopled with animals constructed in accordance with these types, the fauna of no two parts of the world are precisely alike. Difference in conditions of climate or soil, or difference in original character, have produced a diversity, the nature of which is an important object of the naturalist to investigate. For example, fishes of the same name, and apparently of precisely the same character, found on the east and west sides of the Rocky. mountains, present peculiarities which, though slight, are invariable, and which mark a difference of origin or of

condition. But it is not sufficient for the full investigation of the subject to provide the means of studying the living faunas and floras which now characterize different districts ;—science also requires the collection of materials for the investigation of the animal and vegetable forms which existed at the same and different localities at various epochs in the past history of the globe, or, in other words, it is desirous to obtain data for the investigation of the phenomena of life, as it is exhibited in time as well as in space ; and hence attention is also given to the collection of complete suites of the organic remains, particularly of the hitherto unexplored parts of this country.

In reference to the solution of some important questions now pending in relation to natural history, Professor Agassiz has called our attention to several special collections, and as his suggestions are of general interest, I will here mention them. First, he commends to attention the tertiary shells, on account of their bearing on the problem of the mean annual temperature of the globe at different periods anterior to its present geological condition. Different species of these animals exist at present each in water of a given temperature ; and by ascertaining the temperature congenial to each species from actual observation on different parts of the coast, a thermometrical scale would be given by which to determine the climate of any place in the past geological periods in which these animals existed. The United States is most favorably situated for the solution of this question. Its eastern coast extends north and south over more than 23 degrees of latitude, along which shells are everywhere common, and present remarkable changes in their distribution and mode of association. A large collection of these fossil shells from the tertiary beds in different latitudes from Maine to Georgia, properly arranged, would, in time, afford as precise data for ascertaining the mean annual temperature of these shores during the different periods of the tertiary times as an actual series of instrumental observations.

Another collection to which the same distinguished naturalist has called our attention is a series of embryos and young animals of different species. It is a well established fact that animals of a higher type pass from the first inception of life in the embryonic state through a series of forms resembling the lower animals, so that even in the case of man himself the embryo assumes the form of the fish or the reptile. The study, therefore, of a series of animals, selected at different periods of gestation, is of the highest importance in tracing the progress of their separate developments, and also of ascertaining the probable forms under which organized beings may be exhibited in different parts of the present, or in the remains of the past ages of the

world. A collection which might be readily made at one of the great centres, where hundreds of thousands of swine are killed, would enable us to clear up the history of the growth of this animal, and to establish the true relations between the living and fossil quadrupeds of this class, or, perhaps, afford the means of tracing a correct outline of those types which have become extinct, and the forms of which are, perhaps, only preserved in our day in some transient state of the offspring, uncompleted in the womb of our living species. Indeed, so far does Professor Agassiz carry this idea, that he entertains no doubt of the practicability of drawing correct figures of the fossil *Palœtherium* and *Anoplotherium* from the embryos of our present allied animals, viz: of our hogs and horses.

The museum continues to receive large additions from the government surveys and other sources. According to the statement of Prof. Baird, the specimens catalogued at the end of the year 1856 were as follows, viz: Of *mammals*, 2,046; of *birds*, 5,855; of *skulls and skeletons*, 3,060, making in all an aggregate of nearly eleven thousand articles, besides 2,000 mammals in alcohol, and at least 1,200 skins of birds not yet entered on the museum registers.

However valuable these collections may be in themselves, they are but the rough materials from which science is to be evolved; and so long as the specimens remain undescribed, and their places undetermined in the system of organized beings, though they may serve to gratify an unenlightened curiosity, they are of no importance in the discovery of the laws of life.

The collections of the Institution are intended for original investigation, and for this purpose the use of them, under certain restrictions, will be given to any person having the knowledge and skill necessary to the prosecution of researches of this character. It is not the policy of the Institution to hoard them up for mere display, or for the special use of those who may be immediately connected with the establishment. *Cöoperation*, not monopoly, as we have stated in previous reports, is the motto which expresses our principle of action. It is an object of the Institution to induce as many persons as possible to undertake the study of special branches of natural history, and to furnish them, as far as possible, with the means of knowing what has been done, as well as of adding to the stock of existing knowledge. The only return which is required is that proper credit in all cases should be awarded to the Institution for the facilities it has afforded.

Included in the additions to the museum during the last few years from government exploring parties and private individuals have been a number of living animals. Among these were two bald eagles, an

antelope, monkeys, raccoons, two wild cats, a jaguar, and a large grizzly bear, the latter from the Rocky Mountains. Though these objects are of importance in serving as models for drawings by the various artists engaged in figuring the collections of the different surveying and exploring expeditions, it is neither compatible with the means of the Institution, nor the duties of the Secretary and his assistants to take the custody of specimens of this character. We have, however, been relieved from this unenviable charge by the kind cöoperation of Dr. Nichols, Superintendent of the Government Insane Asylum, who has provided suitable accommodations for the animals on the extensive grounds of that institution, and rendered them subservient to its benevolent object in the amusement and consequent improvement of its patients. As they are in the immediate neighborhood of this city, they are readily accessible to strangers, and students of natural history, who visit the seat of government. While presents of this kind evince kind feelings, and are complimentary to the management of the Institution, the expense of transportation in some cases has been rather a heavy tax, and while we cannot very well refuse donations of this character, they would be much more acceptable were they received free of cost.

In connexion with this subject it may be stated that we have frequent applications for exchanges of specimens with foreign institutions; but while we are anxious to diffuse as widely as possible a knowledge of the natural history of this country, and to distribute articles which may serve to verify the Smithsonian publications, still it is not the policy with the present income to collect specimens other than those directly intended to illustrate the productions of the North American continent.

For a detailed account of the operations of the museum, the explorations which have been undertaken during the year at the expense of the government or otherwise, and the sources from which donations have been received, I will refer to the report of Prof. Baird, herewith submitted.

Gallery of Art.—The room apropriated to the gallery of art is still occupied by the series of interesting Indian portraits, by Mr. Stanley. It is to be hoped that Congress will make an appropriation for the purchase of these illustrations of a race of men rapidly disappearing before the advance of civilization. The collection should be kept together and carefully preserved as a faithful ethnological record of the characteristics of the aboriginal inhabitants of the western portion of our continent. It is the most complete collection of the kind now in existence, and it would be a matter of lasting regret were the pictures

sold to individuals, and thus separated. Mr. Stanley, though possessing much enthusiasm and liberality in regard to his art and commendable pride in this collection, will feel compelled, in justice to his family, to dispose of it to individuals, unless Congress becomes the purchaser.

The Institution possesses a valuable collection of engravings, well calculated to illustrate every epoch in the history of the art, as well as the style of the greatest masters. It is desirable that a catalogue be prepared, under the names of the engravers, in alphabetical series and with references to the volume and page, of the authors by whom the pieces have been described and criticised. The smaller engravings should be mounted in portfolios or volumes, and the larger regularly arranged, and where necessary, mounted on sheets of thick paper or paste-board, and placed in portfolios. A sufficient number to illustrate various styles, and also such as are of extraordinary merit, rarity, or cost, ought to be framed as a means of preservation as well as of exhibition.

It was a part of the original programme of organization, to furnish accommodations free of expense for the exhibition of works of art, and since there is no city of the Union visited by a greater number of intelligent strangers than Washington, particularly during the session of Congress, it is, perhaps, one of the best places in our country for this purpose. A few artists during the past year have availed themselves of the advantages thus afforded, and perhaps others would embrace the opportunity were the facts more generally known.

Lectures.—Arrangements have been made for the usual number of lectures during the present session of Congress. The plan previously adopted has been adhered to, namely, to give courses of lectures on particular branches of knowledge, interspersed occasionally with single lectures on particular topics. It may be proper to mention that the amount paid the lecturer is merely intended to defray liberally his expenses, and not as full remuneration for his services. Frequent applications have been made, as in previous years, for invitations to lecture; but as a general rule, the honor has not been extended to those who appeared most solicitous to obtain it. Men of standing and established reputation have principally been chosen, and the discourses which they have delivered have been such as to improve the moral and intellectual character of the audience. All subjects of a political or sectarian character have been excluded.

The following is a list of the lectures* which were delivered during the winter of 1856–'57:

Three lectures by Prof. Jos. Le Conte, of Georgia, on "Coal," and and three lectures on "Coral."

One lecture by J. R. Thompson, Esq., of Richmond, Virginia, on "European Journalism."

One lecture by Dr. J. G. Kohl, on "The History of American Geography."

Five lectures by Rev. J. G. Morris, M. D., of Baltimore, on the "Habits and Instincts of Insects."

Six lectures by Prof. Benjamin Pierce, of Cambridge, Mass., on "Potential Physics."

1. The elements of potential physics. The material universe considered as a machine, as a work of art, or as the manifest word of God.
2. Potential arithmetic.
3. Potential algebra.
4. Potential geometry.
5. Analytic morphology, or the world's architecture.
6. The realization of the imaginary, and the powers of justice and love.

One lecture by Rev. Geo. W. Bethune, D. D., of Brooklyn, N. Y., on "The Orator."

Three lectures by W. Gilmore Simms, Esq., of South Carolina:

1. On the Professions.
2. Ante-Columbian History of America.
3. Ante-Colonial History of the United States.

Eight lectures by Dr. D. B. Reid, of Edinburg, on the "Progress of Architecture in relation to Ventilation, Warming, Lighting, Fire-Proofing, Acoustics, and the general preservation of Health."

The operations of the Institution have been continually expanding, and it is with difficulty they can be kept within the limit required by the Smithsonian fund. So far, therefore, from wanting general fields of usefulness, the opportunity of doing good is only restricted by the amount of means which can be employed.

Respectfully submitted.

JOSEPH HENRY.

WASHINGTON, *January*, 1857.

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* In order to complete the list for the winter of 1856–'57 the lectures delivered after the date of the report have been added.

APPENDIX TO THE REPORT OF THE SECRETARY.

SMITHSONIAN INSTITUTION,
December 31, 1856.

SIR: I beg leave to present herewith a report for the year 1856 of operations of such departments of the Smithsonian Institution as have been intrusted by you to my care.

Respectfully submitted.

SPENCER F. BAIRD,
Assistant Secretary.

JOSEPH HENRY, LL.D.,
Secretary Smithsonian Institution.

I.—PUBLICATIONS.—The eighth volume of the Smithsonian Contributions to Knowledge was published and distributed during the year. In size it exceeds any of those preceding it in the series, embracing 556 pages of text and nine plates. A large portion of the ninth volume is also printed, and it is expected that the rest will be finished early in 1857.

The octavo publications during the year consist of the tenth annual report to Congress and Coffin's Psychrometrical Tables.

II.—EXCHANGES.—The receipts by exchange during 1856, both for the Smithsonian Institution itself and for the other parties for whom it acts as agent, have been unusually great, considerably exceeding those of any previous year, as will be shown by the following table:

The following table exhibits the total of receipts as compared with 1855.

	1855.		1856.	
Volumes—Octavo	717		966	
" Quarto	233		329	
" Folio	87		61	
		1,037		1,356
Parts of volumes and pamphlets—				
Octavo	1,427		1,413	
Quarto	239		383	
Folio	41		38	
		1,707		1,834
Maps, charts, and engravings		26		140
Total		2,770		3,330
Number of distinct donations		1,779		2,331

The copies of the eighth volume of Smithsonian Contributions to Knowledge were all duly forwarded to such addresses in the United States and Europe as were entitled to receive them. Those for Europe

were accompanied, as usual, by the publications of all the American societies, and filled 36 large boxes. The Institution did not receive enough copies of its separate memoirs for distribution at that time, and the transmission to minor societies and individuals was deferred until the begining of 1857. The statistics of the whole will be presented altogether in the next report.

III.—MUSEUM.

A.—*Increase of the Museum.*

In my last report I had occasion to call attention to the very large increase in magnitude of the collections received in 1855 compared with those of preceding years. As many of these had been gathered by parties engaged in government surveys, of which few were in the field in 1856, it was not expected that this year would equal the last in the extent of additions to the museum of the Smithsonian Institution. On the contrary, however, there has been no year in which so many valuable accessions have been made; the pre-eminence consisting not only in the number of specimens, but in their intrinsic value and variety. For details on this subject I must refer to subsequent portions of my report, and shall here only present a comparative table of receipts for the three past years:

	1854.	1855.	1856.
Number of articles received—			
Barrels and kegs	35	26	19
Cans	26	18	23
Jars	175	187	127
Boxes	94	159	234
Bales	—	7	1
Packages	32	79	87
Total	362	476	491
Separate donations	130	229	274
Donors	85	130	160

From the above table it will be seen that the increase in the number of packages of donations, and of donors, during 1856, has been almost as marked as that of 1855 over 1854. I shall now proceed to advert briefly to the most important sources whence these collections were derived, and then mention the principal additions in the different branches of the museum. As in past years, the bulk of the specimens received were collected by government parties, and deposited with the Smithsonian Institution in pursuance of the act of Congress which directs this disposition of all natural history property of the United States which may be in the city of Washington.

a.—THE MEXICAN BOUNDARY LINE.

Survey of the boundary line between the United States and Mexico—Major W. H. Emory, U. S. A., commissioner.—In my last report the

return of the main party under the commissioner was announced, and brief mention made of the important collections gathered during the survey. The party engaged on the western portion of the line, under Lieutenant N. Michler, arrived in Washington early in the present year. The natural history collections were made by Arthur Schott, esq., and were in very great variety, embracing many species new to the fauna of the United States; thus rendering still more just the remarks made in my last report upon the comprehensiveness and value of the natural history results of the United States and Mexican boundary survey.

Fort Yuma.—An important addition to our knowledge of the zoology of the Mexican boundary line was made by Major G. H. Thomas, United States army, assisted by Lieutenant Dubarry, United States army, in a series of the animals of Fort Yuma. This embraced several new species; the most important of which was a *Phyllostome* bat, the first member of that family ever found within the limits of the United States.

b.—REGIONS WEST OF THE MISSOURI.

The government parties engaged in the regions north of the Mexican boundary line and on or west of the Missouri river, and from which collections have been received in 1856, are three in number; the results of which were important and satisfactory in a high degree. The labors of other parties of a more private character working within the same field have also yielded fruits of great value.

1. *The exploration of the Llano Estacado, under Captain J. Pope, United States army.*—This expedition was sent out in 1854 for the purpose of testing the practicability of artesian borings for water in the desert plains of Texas. It returned in October, 1856, after having succeeded in accumulating a large mass of facts and observations respecting the geology, geography, topography, magnetism, meteorology, and other physical features of the climate and soil of the staked plains. But the results of most interest here consist in a very extensive collection of the animals of that little known region, embracing full series of its vertebrata and insects. The collection, in respect to the latter, is indeed of hitherto unexampled extent in the history of government expeditions; Captain Pope having directed particular attention to specimens in this obscure department of American zoology. The result is to be found in sixty boxes of pinned insects of all orders, in great excellence of preservation, and furnishing, not only ample materials for the study of geographical distribution, but likely to throw much light on the character, habits, and changes of many species of western insects, already possessing a painful prominence for their devastations of plants of both wild and cultivated growth.

Complete collections of the mammals, birds, reptiles, and fishes of this region were also made; among them several species entirely new, and others not previously known, except in very different localities.

Large collections in botany, mineralogy, and geology were also made, but have not been received at the Institution.

2. *Exploration of the Missouri and Yellowstone rivers, under Lieut. G. K. Warren, United States army.*—This expedition, accompanied by Dr. F. V. Hayden as geologist and naturalist, left St. Louis in April, and returned in November, having in the mean time explored the whole Missouri, from Council Bluffs to a point eighty miles above the mouth of the Yellowstone, and up the latter to the mouth of the Powder river. Short as was the time actually occupied in the field—scarcely six months—the party not only made the regular astronomical and topographical observations, but also contributed in a high degree to the advancement of natural science, by securing the largest collection in natural history ever obtained by any one government expedition to the West. Some idea of the extent of these collections may be formed from the fact that they embraced one hundred and fifty mammals, six hundred birds, (one hundred and thirty-five species,) skulls in large number, with several skeletons of each of the large quadrupeds of the plains; about forty boxes of selected fossils, weighing several tons, among them an extensive series of the remarkable plants of the tertiary, first discovered in North America by Dr. Hayden on a previous exploration, together with numerous plants, Indian implements, dresses, &c. All the large mammals of the plains, buffalo, elk, deer, bears, wolves, antelope, bighorn, &c., are represented in full by a series of skins, skeletons, and skulls, in perfect condition, fitted at any time to be mounted and placed on exhibition.

3. *Expedition for the construction of a wagon road from Fort Riley to Bridger's Pass, under Lieutenant F. T. Bryan, United States army.*—This party, accompanied by W. S. Wood, esq., of Philadelphia, as collector and naturalist, left St. Louis in May, and returned in November. The collections of the expedition, though exceeded in magnitude by those of Lieutenant Warren and Captain Pope, were yet of very great extent, and embraced a number of species larger than usual in proportion to that of the specimens, owing to the careful selection rendered necessary by the limited amount of transportation. A peculiar interest attached to this party from the fact of its route having been in part along or near that of Major Long's expedition in 1819, who, as is well known, was accompanied as naturalist by the eminent Say. Thirty-seven years had elapsed, and many of the species observed on that occasion, and shortly after described, were either obscurely known or altogether overlooked, owing to the loss in one way or another of the original specimens. It will, then, be a source of no little gratification to those interested in the natural history of America to learn, that in the collections made by Mr. Wood are to be found nearly all the vertebrate species gathered by Say in the way out to the Rocky mountains; those on Say's return route having also been collected by Captains Marcy, Whipple, Gunnison, and Beckwith, a few years ago.

The most important collections made under Lieutenant Bryan consist of the mammals, birds, reptiles, and fishes. Specimens of nearly

all the species observed were obtained, embracing, as did those of the two explorations previously mentioned, several new species.

Exploration of the Upper Missouri to the mouth of the Judith, in 1855, *by Dr. F. V. Hayden.*—Numerous collections made on this occasion by Dr. Hayden were received during the year, and included very many specimens of vertebrata, insects, and fossils of much the same character as those referred to under head of Lieutenant Warren's expedition. It was on this occasion that Dr. Hayden made the discovery on the Judith river of a peculiar formation which, by its reptilian remains, would seem to represent the wealden of England, as suggested by Dr. Leidy.

Explorations of Dr. J. G. Cooper and Dr. George Suckley, United States army.—The final collections of Dr. Cooper made in Washington Territory and California were received in 1856, and closed the important labors of this naturalist, commenced in 1853. These embraced all the departments of natural history, including many species before unknown. This gentleman, as mentioned in a previous report, went out as surgeon and naturalist to Washington Territory with the western division of Governor Stevens' Pacific railroad party, under charge of Captain George B. McClellan; and after the expiration of his engagement remained in the country, chiefly at Vancouver and Shoalwater bay, spending a short time, previous to his return to the Atlantic coast, near San Francisco.

Dr. Suckley, after returning on leave to the United States in 1855, went back in November of that year to Washington Territory in company with a detachment of United States troops. Stationed most of his time at Steilacoom, on Puget Sound, the scene of his former labors, in fact, Dr. Suckley renewed many of his previous collections, and added considerably to his list of species; and sent to Washington many boxes of specimens.* To these two gentlemen, in connexion with J. K. Townsend, esq., we are indebted for a knowledge of the entire natural history of the coast regions of northern Oregon and Washington Territories such as is possessed by but few States—by their labors the vertebrate animals being, not only well known, but the geographical distribution of the species minutely ascertained, and the fullest notices of the habits and peculiarities placed on record. Indeed, it is a serious question whether the species of the Atlantic coast and its adjoining regions are as well known as those of the Pacific slope, through the labors of Drs. Cooper, Suckley, Townsend, Gambel, Heermann, Kennerly, Webb, Newberry, and J. F. Hammond; Lieutenant W. P. Trowbridge and his assistants, Messrs. James Wayne, A. Cassidy, T. A. Szabo; Major G. H. Thomas, Lieutenant Dubarry, and Messrs. Nuttall, Bell, Bowman, Schott, Ayres, Gibbons, Taylor, Gibbs, Grayson, Samuels, Hutton, and others.

From Dr. J. F. Hammond, United States army, many valuable

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* Among these were some skins of mountain goats, presented by Lieutenant Nugen, United States army.

collections, gathered in southern California, were received, furnishing not only several species not previously in our collections, but also supplying most important materials for determining the distribution of the animals of the western slope generally.

Mr. A. S. Taylor, of Monterey, has furnished a variety of species, while A. J. Grayson, esq., has supplied a number of birds of much interest.

Other California collections, of greater or less extent, were received from Capt. Stone and Dr. Antisell, and A. Campbell, esq.

Explorations in the vicinity of Petaluma, (Cal.) by E. Samuels, esq.—Brief mention was made in my last report of the fitting out of Mr. Samuels by the Boston Society of Natural History and the Smithsonian Institution, aided by the liberality of the United States mail line to California, via Panama. Mr. Samuels returned in July last, having thoroughly explored the field of his labors, and gathered a rich collection of specimens, embracing many rare and new species. The liberal promises of the Pacific Mail Steamship Company, the Panama Railroad Company, and the United States Mail Steamship Company, have been more than realized in the free passage home given to Mr. Samuels and all his large collections—an act of generosity which may well excite the attention and recognition of the lovers of science. Nor should less meed of praise be awarded to Messrs. Wells, Fargo & Co. for their free transmission to San Francisco of Mr. Samuels' boxes, thus facilitating their semi-monthly despatch to Washington.

It may, perhaps, not be out of place here to state that the above mentioned mail line still continues its kind offices by transporting, free of charge, all packages of the Smithsonian Institution containing books of specimens of natural history. The United States mail line, also, has furnished free freight of a similar character from Cuba and New Orleans to New York.

The results of Mr. Samuels' explorations will shortly be published in connected form in the journal of the Boston Society of Natural History, illustrated with the necessary plates and figures.

Collections in Texas, Kansas, Nebraska, and Utah.—In addition to the great collection made by Capt. Pope, Lieut. Bryan, Lieut. Warren, and Dr. Hayden in these territories, several others have been received, of more or less importance, which will be referred to under their appropriate head. A collection of plants from the vicinity of Fort Belknap, made by Dr. Vollum, United States army, and of plants and animals from Fort Chadbourne, by Dr. E. Swift, United States army, have added to our knowledge of the natural history of Texas. A collection of reptiles and birds from Fort Riley, Kansas, was also received from Dr. W. F. Hammond.

C.—REGIONS EAST OF THE MISSOURI.

It will be impossible, with the limits assigned me, to go into detail respecting the collections from this portion of the United States, although much of great value has been received. The principal con-

tributors will be referred to hereafter, under the head of special departments of the museum, as well as in the alphabetical list of "additions to the museum."

d.—OTHER PORTIONS OF THE WORLD.

The year 1856 has witnessed the safe and successful return of the two naval explorations sent out in the early part of 1853, and diligently occupied ever since in fulfilling the objects of their mission. These were, the expedition for the survey of the China seas and Behring Straits, (first under command of Capt. C. Ringgold, United States navy, and subsequently under Capt. J. Rodgers, United States navy,) and the expedition for the exploration of the La Plata and its tributaries, under Capt. T. J. Page, United States navy.

The Behring Straits expedition, accompanied by Wm. Stimpson as zoologist and Charles Wright as botanist, visited the island of Madeira, Cape of Good Hope, China seas, Japan, Kamtschatka, Behring Straits, and the coast of California, returning from Tahiti, via Cape Horn, in the very short time of seventy-four days. The natural history results were of great magnitude, filling many boxes and barrels, and embracing very many new and rare species. Some idea of the value of the collection may be formed from the following brief enumeration of the animals brought home:

Vertebrata	846	species.
Insects	400	"
Crustacea	980	"
Annileds	220	"
Mollusca	2,359	"
Radiata	406	"
Total	5,211	"

Of these, it is probable that more than one-half are undescribed. The plants have not yet been assorted, but it is believed that they will be not inferior in extent to the animals. They occupy in the original boxes and bales a bulk of over 100 cubic feet.

Mr. Wright left the vessel at San Francisco, and returned via Nicaragua. He there made a valuable collection of plants and animals, but was prevented from completing his explorations by the internal troubles of the country. He has since gone to Cuba, to investigate the botany of that island.

It may be proper to remark here, that the whole of a very rich collection of invertebrates made in the Arctic seas was dredged from the vessel under the immediate superintendence of Captain Rodgers himself, while the scientific corps was engaged in another portion of Behring's Straits.

The exploration and survey of the La Plata and its tributaries, under Captain T. J. Page, though consisting of but a single steamer, the Water Witch, of only 400 tons, and unprovided with naturalists, has yet accomplished much for natural science in the collection of very full series of the birds, reptiles, fishes, insects, and plants of the

country, with many interesting specimens of minerals, fossils, woods, and other native products. A point of special attention was that of plants useful in the materia medica, and of these many new and rare kinds were obtained, which cannot fail to be of economical importance.

In making these collections, Captain Page was ably seconded by Dr. Carter, surgeon of the vessel, Lieutenant Powell and the other officers, as well as by E. Palmer, horticulturalist. In addition to the specimens themselves, many valuable notes on the habits and peculiarities of the species were obtained.

Mr. Palmer left the expedition before its return on account of ill health, and while waiting a passage home made some additional collections of reptiles, fishes, and insects, of much interest.

At the present time, all of the collections of these two naval expeditions are stowed in the Smithsonian building, waiting some action of Congress by which they may be published to the world. Funds are needed to make the necessary drawings of new or unfigured species, and to compensate naturalists for preparing the different reports.

e.—SYSTEMATIC STATEMENT OF ADDITIONS TO THE MUSEUM.

Under the present head, I can only mention, in brief terms, the most important additions made in the different classes of animals, referring for particulars to the alphabetical list of contributions. The collections made by the government expeditions will be discussed at length in their official reports. In the systematic catalogues also of the collections of the Institution, in preparation for publication, as soon as their extent will warrant, will be found a careful and detailed indication of the donor and locality of every specimen. It may, however, be well to extend the table of catalogue specimens, given on page 54 of last year's report, to 1856, for the sake of exhibiting the increase in several departments.

	1851.	1852.	1853.	1854.	1855.	1856.
Mammals	None.	114	198	351	1,200	2,046
Birds	....	....	....	4,353	4,425	5,855
Skulls and skeletons	911	1,074	1,190	1,275	2,050	3,060

To the above enumeration, however, must be added nearly 2,000 mammals in alcohol, and at least 1,200 skins of birds, not yet entered on the museum register.

No count has been made of the jars filled during the year with specimens in alcohol. It is believed, however, that the number of 9,171, may be safely increased to nearly 12,000.

Mammals.—It is in this class that the additions have been most extensive and important, the number of the larger species especially,

being very great. Out of the whole number of additions already catalogued, 846, the following are those of the larger animals.

Black Bear, *Ursus americanus*	1	Jaguar, *Felis onza*	1
Cinnamon Bear, *Ursus cinnamomeus*	1	Prairie Dog, *Cynomys ludovicianus*	50
Grizzly Bear, *Ursus ferox*	10	Beaver, *Castor canadensis*	7
Racoon, (*two species*)	6	Common Deer, *Cervus virginianus*	18
Wolf, *Lupus occidentalis*	10	Black Tail Deer, *Cervus columbianus*	7
Prairie Wolf, *Lupus latrans*	6	Mule Deer, *Cervus macrotis*	11
Red Fox, *Vulpes fulvus*	6	Elk, *Cervis canadensis*	12
Gray Fox, *Vulpes Virginianus*	6	Antelope, *Antelcpe americana*	18
Badger *Taxidea labradoria*	5	Bighorn, *Ovis montana*	5
Wild Cat, *of three species*	19	Mountain Goat, *Capra montana*	4
Panther, *Felis concolor*	5	Buffalo, *Bison americana*	5

As might readily be inferred, most of the above mentioned specimens were received from Captain Pope, Lieutenant Warren, Lieutenant Bryan, and Dr. Hayden; those collected by Lieutenant Warren being of extraordinary variety and number.

Continuations of the collections on the west coast, both of mammals and birds from Doctors Cooper, Suckley, and Hammond, Mr. Samuels and others, have been of much interest. Messrs. Kennicott, Jenks, Pastel, Wilson, Curtis, and others, have contributed many specimens from the Atlantic region.

Several rich collections of European and Siberian mammals have been received, and furnish the much desired opportunities of comparison with American species. Among them may be mentioned *Dipus jaculus*, *acontion*, *sagitta*; *Meriones opimus*, *tamaricinus*; *Spermophilus guttatus*, *eversmanni*, *erythrogenys*; *Cricetus arenarius*, *frumentarius*; *Myodes novegicus*, *torquatus*, *obensis*, *lagurus*, *obscurus*, *schisticolor*; *Arvicola rutilus*, *oeconomus*; *Lagomys alpinus*; *Tamias pallasii*.* *Mustela sibirica*, *Feliscatus*, *&c.*—These have been received from Dr. George Hartlaub, of Bremen, Dr. F. Brandt, of St. Petersburg, and Maximilian, Prince of Wied.

A deficiency in the collection last year of the *Geomys pinetis*, or pouched rat of Georgia, sometimes called "salamander," has been supplied by specimens received from Dr. Baldwin, Dr. Gesner, and Mr. Burgwyn.

Birds.—Many specimens of birds have been received from various parts of the world, and among the North American specimens are several new species. A collection of nearly 100 Australian species was presented by Mr. Warfield. Some rare birds from Bolivia were deposited by Mr. Evans.

Reptiles.—Among many, the most interesting specimens of reptiles added during the year are two of *Lepidosiren annectens* from the

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* By this name I denote the species of ground squirrel found in Siberia by Pallas, and by him considered the same with the ground squirrel of the United States. The most superficial comparison of the two shows them to be distinct, and as the American animal was first described by Linnaeus as *Tamias striatus*, it must retain the name. In the necessity for a new name for the Siberian species, I propose that of the discoverer, in the absence, as far as I can ascertain, of any other.

west coast of Africa, presented by Sir William Jardine. This almost completes the rich series of ichthyoid reptiles in the Smithsonian collection, the only deficiency being that of the gigantic salamander of Japan, (*Siiboldia.*)

Fishes.—The number of fishes received has not been very great, compared with previous years, as but few portions of the United States lack representatives in the Smithsonian museum at the present time.

Insects.—But few insects have been added during the year, with the exception of those already referred to under the head of government expeditions.

Other Invertebrates.—A large collection of 100 species of *Achatinella*, from the Sandwich Islands, was presented by Dr. Newcomb, and of shells and crustacea of Florida and Michigan, by O. M. Dorman, Esq.

Plants.—The principal plants received have been from Texas, collected by Drs. Swift and Vollum, of the United States army.

Fossils and Minerals.—The principal private collections under this head, besides those contributed by Dr. Hayden, were received from I. Lippman, of Saxony, the K. L. C. Akademie of Breslau, and the Naturforschende Gesellschaft, of Emden.

Living animals.—These consisted chiefly of a Prairie Dog (*Cynomys ludovicianus*,) Sage Rabbit (*Lepus artemisia*,) and Prairie Fox (*Vulpes macrourus*,) collected by Lieutenant Warren and party. Some living animals were brought home by Captain Page, as a Jaguar, and Nutria (*Myopotamus coypus.*) The latter has since died. Mr. David Miller presented a Pennsylvania Fox Squirrel (*Sciurus cinereus.*) Many specimens of *Arvicola* and *Hesperomys* (mice) were transmitted by Robert Kennicott.

Several hundred living turtles were received and transmitted to Professsor Agassiz for examination.

The living animals received from time to time have been found of great use, as studies for the artists engaged in making drawings for the various government reports. Several of the specimens, as the Spermophiles, Prairie Dog, Prairie Fox, Antelope, &c., had never been figured previously, except from distorted, dried skins.

In the following tables will be found references to the regions from which collections have been received, and to the nature of the specimens; and at the end a full list of all the donations, arranged alphabetically by donors. In some cases it has been impossible to ascertain the source of collections, owing to the omission by the donor of his name and address.

I.—Geographical Index to Specimens received.

Vancouver's island.—Turner.
Washington and Oregon.—Carter, Cooper, Newberry, Nugen, Suckley.
California.—Antisell, Campbell, Cooper, Dubarry, Emory, Grayson, Hammond, Samuels, Stone, Suckley, Taylor, Thomas, Trowbridge.
Utah.—Carrington.
Nebraska.—Atkinson, Bryan, Hayden, Stevens, Walker, Warren, Watson.
Kansas.—Bryan, Carleton, Hammond.
Missouri.—Agassiz, Engelmann, Riddell, Wilson.
Texas.—Antisell, Pope, Swift, Vollum.
New Mexico.—Bowman.
Arkansas.—Burke.
Mississippi.—Bellman, Teunison.
Florida.—Baldwin, Burgwyn, Churchill, Dorman, Savery, Smith, Welsh, Würdemann.
Georgia.—Churchill, Gesner, Glover, Jones, Leconte, Postell, Wilson.
South Carolina.—Agassiz, Curtis.
North Carolina.—Bridger, Hunter.
Virginia.—Brakeley, Brooks, Cabanis, Easter, Hall, Hotchkiss, Jenks, Joynes, McCue, Massy, Tompkins, Tuley.
Maryland and District of Columbia.—Lowndes, Moss, Newberry, Younger.
Pennsylvania.—Baird, Brickenstein, Brugger, Cassin, Mackey, Miller, Stauffer, Thickstun.
New Jersey.—Ashmead, Baird, Brown, Cooper.
New York.—Baker, Benton, Byram, Davis, Guest, Hale, Howell, Reid, White.
Massachusetts.—Atwood, Brewer, Jenks, Jenkins.
Vermont.—Thompson.
New Hampshire.—Harvey.
Maine.—Hamlin.
Michigan.—Dickinson, Dorman, Newberry, Reynolds.
Wisconsin.—Bell, Hoy.
Illinois.—Dorman, Kennicott.
Iowa.—Bidwell, Glover, Odell.
Ohio.—Kirtland, Luther, Merrick, Newberry, Newton, Spence.
Indiana.—Cox.
Tennessee.—Mitchell.
Kentucky.—Bibb.
Nova Scotia.—Dawson, Downes, Gilpin, Ross, Willis.
Newfoundland.—Skues, Stabb.
Mexico.—Bobadilla, Hartlaub.
Nicaragua.—Anderson, Smith, Wright.
Cuba.—Poey.
Panama.—Cooper, Evans, Raymond, Rowell, Suckley.
Paraguay.—Page, Palmer.
Brazil.—Cabanis, Page.

Bolivia.—Evans, Fry.
Jamaica.—Wilson.
England.—Denny, Jardine.
Germany.—K. L. C. Akademie, Breslau, Lippmann, Max., Pr. Wied, Naturforschende Gesellschaft, Emdon.
Siberia.—Brandt, Hartlaub.
Africa.—Jardine.
Sandwich Islands.—Newcomb.
North Pacific seas.—Rodgers.
Australia.—Warfield.

II.—SYSTEMATIC INDEX TO SPECIMENS RECEIVED.

Mammals.—Antisell, Atkinson, Baird, Baker, Baldwin, Bell, Bidwell, Byram, Brakeley, Brandt, Brewer, Bridger, Bryan, Burgwyn, Carleton, Cooper, Curtis, Davis, Dawson, Denny, Downes, Dubarry, Easter, Emory, Engelmann, Gesner, Gilpin, Glover, Grayson, Hale, Hall, Hammond, Hartlaub, Hayden, Howell, Jardine, Jenks, Jones, Kennicott, Leconte, Lowndes, Luther, Massey, Max., Pr. Wied, Miller, Moore, Mitchell, Newberry, Newton, Nugen, Odell, Page, Poey, Pope, Postell, Reid, Riddell, Rodgers, Rowell, Samuels, Savery, Skues, Smith, Stabb, Stevens, Swift, Suckley, Taylor, Teunison, Thickstun, Thomas, Thompson, Trowbridge, Tuley, Warfield, Warren, Watson, Wilson.

Birds.—Bidwell, Bryan, Cabanis, Cassin, Cooper, Davis, Easter, Emory, Evans, Glover, Grayson, Hammond, Hartlaub, Hayden, Kirtland, Luther, Page, Pope, Rodgers, Samuels, Savery, Stabb, Swift, Suckley, Trowbridge, Warfield, Warren, Würdemann.

Reptiles.—Agassiz, Antisell, Ashmead, Baldwin, Brakeley, Brickenstein, Bridger, Baird, Bryan, Cabanis, Churchill, Denny, Dickinson, Emory, Gesner, Glover, Jardine, Jones, Kennicott, Mitchell, Newberry, Page, Palmer, Poey, Pope, Reynolds, Rodgers, Rowell, Samuels, Smith, Stauffer, Swift, Suckley, Taylor, Teunison, Thickstun, Thomas, Walker, Warren, Wilson, Wright, Würdemann, Younger.

Fishes.—Baird, Bibb, Brugger, Bryan, Churchill, Cox, Denny, Emory, Engelmann, Evans, Guest, Jardine, Kirtland, Mitchell, Page, Palmer, Pope, Rodgers, Samuels, Suckley, Taylor, Tennison, Trowbridge, Warren, Welsh, Würdemann.

Insects.—Baldwin, Bowman, Bryan, Cooper, Emory, Mackey, Moss, Palmer, Pope, Raymond, Rodgers, Rowell, Samuels, Swift, Suckley, Taylor, Walker, Warren.

Other Invertebrates.—Antisell, Atwood, Bellman, Bibb, Bidwell, Bryan, Dorman, Luther, Newcomb, Plant, Pope, Rodgers, Samuels, Smith, Stone, Suckley, Willis.

Plants.—Brown, Carter, Churchill, Cooper, Joynes, Raymond, Rodgers, Swift, Vollum, Wright.

Fossils and Minerals.—Bidwell, Bobadilla, Brooks, Burke, Campbell, Carrington, Denny, Fry, Hammond, Harvey, Hayden, Horner, Hotchkiss, Hunter, Jenkins, Jenks, K. L. C. Akad., Lippmann, McCue, Merrick, Naturf. Ges., Emden, Newberry, Ross, Spence, Taylor, Thickstun, Turner, Warren, Wilson.

Miscellaneous.—Hamlin, Hoy, Swift, Tompkins, Trübner, White, Wilson.

B.—*Work done in the Museum.*

The various collections of the year have been unpacked, assorted, and catalogued as fast as received. Books have been opened for the registry of the fishes and invertebrates of the series, which will be labelled and entered as rapidly as circumstances will admit.

C.—*Distribution and use of the Smithsonian Collections.*

As in the previous years, the collections of the Smithsonian Institution have been freely open to the use of any persons engaged in original research, and many specimens also distributed as exchanges. The entire series of turtles has been sent to Professor Agassiz, to be used in the preparation of his work, and many hundreds of living ones were procured for him. Dr. Wyman has had many specimens and preparations of salamanders and ichthyoid reptiles. Eggs of North American birds have been furnished to Dr. Brewer, coleoptera to Dr. Leconte, neuroptera to Mr. Uhler, hymenoptera to M. Desaussure; seeds to the United States Patent Office; shells to Dr. Gould, Mr. Lea, Hugh Cuming, and Mr. Cooper; birds to the Bremen museum and to Dr. Hoy; living reptiles to the Zoological Society of London; fossils to Dr. Leidy, &c., &c.

D.—*Present Condition of the Museum.*

The present condition of the museum of the Smithsonian Institution may be summed up as follows:

1st. Its collection of the vertebrate animals of North America, including skins, specimens entire in alchohol, and skeletons and skulls, is in every department, the richest in the world in materials for illustrating species and their geographical distribution.

Of invertebrate animals—as insects, shells, crustacea, &c., plants, minerals, rock specimens, and fossils—its collections from the western half of the United States are incomparably superior to all others, while from the eastern portion of the continent it has very good series, though surpassed in the extent of the different divisions by a number of others, both public and private. A single exception may perhaps be found in the private cabinet of coleoptera belonging to Dr. Leconte, which is by far the richest known in the species of North America generally. It

will, however, be a comparatively easy matter to complete the deficiencies of the Smithsonian collection so as to furnish, in a few years, as perfect a collection of the natural productions of North America generally as could reasonably be expected. In most cases, it will be merely necessary for the Institution to express a desire to possess such collections from the Atlantic and middle portions of the continent to have them offered spontaneously. Hitherto it has not been considered expedient to throw the doors open very wide for the reception of the more common and better known species.

Of collections from other parts of the world, the Institution possesses excellent series in many branches of natural history from Paraguay, Chili, Europe, Siberia, China, Japan, South Africa, and the Pacific ocean generally. The results of the Paraguay expedition under Captain Page, United States navy, and the Behring Straits expedition, first under command of Captain Ringgold, and then under Captain Rodgers, are of pre-eminent magnitude and value, far exceeding, in many respects, those of any previous exploring parties to the same region.

In illustration of the preceding remarks respecting collections in North American zoology, it may be stated that the series of vertebrata is almost complete, very few known species being wanting. Skins of all the more prominent mammals, as buffalo, elk, deer of five species, antelopes, mountain goats, bighorn or mountain sheep, black, cinnamon, and grizzly bears, wolves, foxes, beaver, badger, otters, prairie dogs, and marmots, peccaries, panther, jaguar, ocelot or tiger cat, lynxes of four species, wolverine or carcajou, &c., are now packed away within the walls of the Smithsonian Institution, ready at any time to be mounted. All the species interesting to the hunter, the traveller, the farmer, or the man of science can here be examined or studied. The total number of North American species cannot be less than two hundred, exclusive of bats, seals, and cetaceans. Messrs. Audubon and Bachman describe about one hundred and fifty North American species of mammals. This Institution possesses about one hundred and thirty of these; and about fifty additional species have already been detected, although the examination of the entire collection has not yet been completed.

Of North American birds, the Institution possesses nearly all described by Audubon, and at least one hundred and fifty additional species.

The registered and catalogued specimens of quadrupeds amount to 2,040, of birds to 6,055, of skeletons and skulls to 3,060, nearly all North American. To these, however, must be added at least 2,000 North American quadrupeds in alcohol, and 1,200 birds not yet entered

Of reptiles, the North American species in the museum of the Smithsonian Institution amount to between 350 and 400. Of the 150 species described in Holbrook's North American Herpetology, the latest authority on the subject, it possesses every genuine species, with one or two exceptions, and at least two hundred additional ones. It has about 130 species of North American serpents for the 49 described by Holbrook.

Of the number of species of North American fishes, it is impossible to form even an approximate estimate, the increase having been so great. It will not, however, be too much to say that the Institution has between four or five hundred species either entirely new or else described first from its shelves.

Of skeletons and skulls of North American vertebrata, the Smithsonian series is very full, embracing, as shown by a preceding table, over 3,000 specimens.

The collection of minerals and fossils, (including those gathered by nearly all the United States geological surveys, as by Dr. D. D. Owen, C. T. Jackson, Foster and Whitney, Evans, &c.,) are all carefully classed and catalogued, so as to correspond with and fully illustrate the reports of these gentlemen. There is also a large collection of geological specimens, made many years ago in New Mexico and Texas, as well as in Sonora, Chihuahua, and other portions of northern Mexico, which, with the accompanying notes, furnish indications of many mineral regions and mining localities now totally unknown to the people of the United States. Hints are to be derived from a careful study of this collection of the highest importance in the development of the mineral region along the Mexican boundary line.

It may, perhaps, be well here briefly to mention the government expeditions, by which these collections were made from time to time, under the authority of the departments. The present and preceding reports contain much fuller details concerning them.

A.—*Geological Surveys.*

1. The survey of Wisconsin, Iowa, Minnesota, and a portion of Nebraska, by Dr. David Dale Owen.
2. The survey of the Lake Superior district, by Dr. Charles T. Jackson.
3. The survey of the same region, by Messrs. Foster and Whitney.
4. The survey of Oregon, by Dr. John Evans.

B.—*Boundary Surveys.*

5. The survey of the line between the United States and Mexico, first organized under honorable J. B. Weller, as commissioner, and Major W. H. Emory, as chief of the scientific department, then under John R. Bartlett, commissioner, and Colonel J. D. Graham, chief of the scientific corps, succeeded subsequently by Major W. H. Emory, then under General R. B. Campbell, commissioner, and Major W. H. Emory, chief of the scientific corps.
6. The survey of the boundary line of the Gadsden purchase, under Major W. H. Emory, commissioner.

C.—*Surveys of a Railroad route to the Pacific.*

7. Along the 47th parallel, under Governor I. I. Stevens.
8. Along the 38th and 39th parallel, under Captain J. W. Gunnison.
9. Along the 41st parallel, under Captain E. G. Beckwith.
10. Along the 35th parallel, under Lieutenant A. W. Whipple.
11. In California, under Lieutenant R. S. Williamson.
12. Along the 32d parallel, western division, under Lieutenant J. G. Parke.
13. Along the 32d parallel, eastern division, under Captain J. Pope.
14. In a portion of California, under Lieutenant J. G. Parke.
15. In northern California and Oregon, under Lieutenant R. S. Williamson.

D.—*Miscellaneous Expeditions under the War Department.*

16. Expedition along the 32d parallel, eastern division, for experimenting upon artesian borings, under Captain Pope.
17. Exploration of Red river, under Captain R. B. Marcy.
18. Survey of Indian reservation in Texas, under Captain R. B. Marcy.
19. Exploration of the upper Missouri and Yellowstone, under Lieutenant G. K. Warren.
20. Construction of a wagon road from Fort Leavenworth to Bridger's Pass, under Lieutenant F. T. Bryan.

E.—*Naval Expeditions under the Navy Department.*

21. The United States naval astronomical expedition in Chile, under Lieutenant J. M. Gilliss.
22. The Japan Expedition, under Commodore M. C. Perry.
23. Exploration of the China seas and Behrings Straits, first under command of Captain C. Ringgold, then under Captain J. Rodgers.
24. Exploration of the La Plata and its tributaries, under Captain T. J. Page.
25. Exploration of the west coast of Greenland and Smith's sound, under Dr. E. K. Kane.

The preceding enumeration embraces the government explorations, by which collections of various kinds were made to a greater or less extent, and deposited with the Smithsonian Institution, in pursuance of the law of Congress. The government expeditions, the collections of which are now deposited at the Patent Office, are as follows:

1. The United States Exploring Expedition, under Captain Wilkes.
2. The geological surveys of the northwest in 1840, under Dr. D. D. Owen.
3. The exploration of the Salt Lake valley, under Captain H. Stansbury.
4. The exploration of the Creek boundary line, and of the Zuñi river, under Captain L. Sitgreaves.

5. The Amazon expedition under Lieutenants Herndon and Gibbon.

It will thus be seen, that of thirty government explorations, the collections of five-sixths or twenty-four, are now deposited with the Smithsonian Institution; the remaining ones, one-sixth in number, are still in the Patent Office, though not all on exhibition. The same proportion as above will pretty nearly indicate the comparative magnitude of the collections in the two buildings. The disproportion in favor of the Smithsonian collections will be still greater if we except the extensive series of implements, utensils, clothing, and fabrics generally of the Pacific islands, as collected by Captain Wilkes. To realize the difference between the two collections, it must be understood that at the present time all the Smithsonian collections are packed away in the smallest possible compass, very few specimens mounted, the alcoholic collections crowded closely together in five or six different rooms; the shells, minerals, fossils, &c., necessarily boxed up and stowed away in basement rooms.

E.—*Alphabetical Index of Additions to the Museum of the Smithsonian Institution during the year* 1856.

Professor Agassiz.—Three specimens *Emys serrata* from Charleston, South Carolina; *E. belli*, *E. troostii*, and *E. elegans* from Osage river; *E. mobilensis* from Mobile.

Lieutenant Anderson.—One *Dryophis*, two *Istiophorus*, and ten skins of birds from Greytown, Nicaragua.

Dr. Antisell.—Two boxes fossils and minerals from California; skeleton of rattlesnake and spermophile; skin of toad from the Gila river; Hermit crab from Matagorda, Texas.

Charles Ashmead.—*Salamandra tigrina* from Beesley's Point, New Jersey.

E. G. Atkinson.—Skin of spotted buffalo calf from Fort Pierre.

Captain N. Atwood.—Three fresh specimens of *Euryale* from Cape Cod.

S. F. Baird.—Fishes in alcohol; skeletons and jaws of fishes; small mammals from Beesley's Point, New Jersey, and Carlisle, Pennsylvania.

M. Baker.—Skins of fisher or black cat (*Mustela canadensis*) and weasel, skulls of bear, deer, minks, otter, fisher, and martin, from Essex county, New York.

Dr. Baldwin.—Bottle insects, living *Testudo polyphemus* or *gopher* and *Geomys pinetis* or salamander, from Jacksonville, Florida.

J. G. Bell.—Box with two rabbits (*Lepus sylvaticus*) from Wisconsin.

C. Bellman.—Mollusca from Biloxi, Mississippi.

Dr. J. H. Benton and W. E. Guest.—*Lucioperca*, with tumor on head.

Dr. George R. Bibb.—Blind fish and crustacea from the Mammoth Cave, Kentucky.

Dr. E. C. Bidwell.—Skins of birds and mammals, fossils, and shells, from Iowa.

Don J. B. Bobadilla.—Fragment of tusk of mastodon from Mexico, called by Dr. Weidner *Duranzotherium bobadillense.*

Captain A. Bowman, U. S. A.—Specimens of cochineal collected near Fort Stanton, New Mexico, lat. 34°.

J. and A. Brakeley.—Skins of deer and other mammals, skulls of mammals, living rattlesnakes, young *Lynx rufus* in flesh, bones of deer, turkey buzzard, from western Virginia.

Dr. F. Brandt.—Twelve skins Siberian mammals from eastern Siberia.

Dr. T. M. Brewer.—Mammals from Massachusetts.

J. H. Brickenstein.—Living terrapins from eastern Pennsylvania.

J. L. Bridger. –Living snakes, terrapins, fox squirrels, from North Carolina.

J. S. O. Brooks.—Crystallized salt from Kanawha, Virginia.

Dr. George G. Brown.—American amadou from New Jersey.

Samuel Brugger.—One can reptiles and fishes from Potter county, Pennsylvania.

Lieutenant F. T. Bryan, U. S. A.—Six boxes, one keg, containing alcoholic specimens, birds, mammals, and skeletons, from United States wagon road expedition to Bridger's Pass.

W. H. K. Burgwyn.—*Geomys* or "salamander" from Florida.

Rev. John Burke.—Minerals and fossils from Fort Washita.

Dr. George Cabanis.—Living land turtle, roots of Tuckahoe from Virginia.

Dr. J. Cabanis.—Skins of Vireo from Brazil.

E. N. Byram.—Mice and moles from Long Island.

Albert Campbell.—Fossil plant from Santa Inez, California.

Major J. H. Carleton, U. S. A.—Two foetus of buffalo from the plains.

Albert Carrington.—Coals from Utah.

M. Carter.—*Ceanothus occidentalis* from Oregon.

J. Cassin.—Skins of *Loxia leucoptera* and *Americana.*

General Churchill, U. S. A.—Four living gophers, (*Testudo polyphemus,*) four *Emys terrapin*, *Echineis*, *Syngnathus*, and serpents; seeds of plants, from Georgia and Florida.

Dr. J. G. Cooper.—Mammals, birds, and plants from California and Washington Territories. Living turtles from Panama.

William Cooper.—Eighteen skins of mammals.

E. T. Cox.—Skin of *Labrax* from Indiana.

Rev. M. A. Curtis and Sons.—Skins of *Sigmodon*, *Reithrodon*, and *Hesperomys*, mammals and reptiles in alcohol, from South Carolina.

H. Davis.—Mammals and birds from Waterville, New York.

J. W. Dawson.—Specimens of *Jaculus* from Nova Scotia.

H Denny.—Mammals, reptiles, fishes, and fossils, from England.

W. C. Dickinson.—*Menobranchus* from Portage Lake, Lake Superior.

O. M. Dorman.—Shells from Michigan and Illinois. Shells and crustacea from Florida.

J. Downes.—Skin, *Lepus glacialis*, from Newfoundland. *Hesperomys* from Nova Scotia.

Dr. J. D. Easter.—Three skins of mice from Virginia. *Cardinalis Virginianus* (red bird) in flesh from Harper's Ferry.

Major W. H. Emory, U. S. A.—Mammals and birds, reptiles and fishes, insects and shells, collected by Arthur Schott, from San Diego, via Camp Yuma, to El Paso.

Dr. Engelmann.—Cask of fishes and six skins squirrels from St. Louis.

M. Evans.—*Hemiramphus* and *Ailurichthys* from Panama. Box of Bolivian birds. Deposited.

W. A. Fry.—Sulphate of lime encrusted with quartz from the Andes.

D. W. Gesner.—Jar reptiles and mammals, skulls, from western Georgia.

A. J. Grayson.—Birds, mammals, fishes, and eggs, from California.

Dr. S. E. Hale.—Skins and skulls of mammals from Essex county, New York.

Dr. John P. Hall.—Deformed pig from Fairfax county, Virginia.

A. C. Hamlin.—Cast of ancient inscriptions on rock from Maine. Casts of fossil cetacean from Bangor.

Dr. J. F. Hammond, U. S. A.—Birds and mammals from California.

Dr. W. A. Hammond, U. S. A.—Box of minerals and jar of alcoholic specimens from Kansas.

Dr. G. Hartlaub.—Skins of Siberian mammalia, skins of birds of Mexico and Cuba.

M. Harvey.—Minerals from Hampshire county, New Hampshire.

Dr. F. V. Hayden.—Skins of birds, skins and skulls of black-tail deer, antelope, mountain sheep, beaver, prairie dogs, and other mammals; reptiles, fishes, and mammals in alcohol; shells, fossil remains, &c., collected in 1854 and 1855, on the Upper Missouri.

John Hitz.—Cones and seeds of *Pinus cembra* from Switzerland.

Dr. Horner, U. S. N.—Box of minerals.

J. Hotchkiss.—Fossil bone of deer from Virginia.

Robert Howell.—Specimens of mammals from Tioga county, New York.

Dr. P. R. Hoy.—Box Indian antiquities from Wisconsin.

Dr. C. L. Hunter.—Rutile and Lazulite from North Carolina.

Sir W. Jardine.—Mammals, fishes, reptiles, &c., from England. *Lepidosiren annectens* from Africa.

Captain T. A. Jenkins, U. S. N.—Minerals and rocks from Gay Head.

J. W. P. Jenks.—Mammals from Middleboro', Massachusetts.

W. Jenks.—Silicified wood from Alexandria, Virginia.

Dr. Joseph Jones.—Reptiles and mammals in alcohol, from Colonel's island, Georgia.

J. R. Joynes.—Living plants from the eastern shore of Virginia.

K. L. C. Akademie der Naturforscher, Breslau.—Minerals from Germany.

Robert Kennicott.—Mammals, reptiles, and fishes, skins and in alcohol, living serpents, salamanders, and mammals, from Illinois.

Dr. J. P. Kirtland.—Skins *Bombycilla garrula,* 1 jar of fishes, skin of wolf and squirrels from Cleveland, Ohio.

J. Lippman.—Minerals, (148 specimens,) from Schwarzenberg, Saxony.

B. O. Lowndes.—*Arvicola pinetorum* (field mouse) from Bladensburg, Maryland.

S. M. Luther.—Eggs, shells and skin of mink from Portage county, Ohio.

J. M. Cue.—Fossil bones of deer and woodchuck from Augusta county, Virginia.

R. B. Marcy, U. S. A.—Box of minerals and fossils from Fort Belknap.

A. W. Massey.—Skins of raccoon, gray fox, and jar of mammals from Spottsylvania, Virginia.

Maximilian, Prince of Wied.—Skins of European mammals.

Professor F. Merrich.—Fossil fishes from Delaware, Ohio. Deposited.

Dr. Ed. Merrill.—2 packages moss from Louisiana.

D. Miller, jr.—Living fox squirrel from Pennsylvania.

Mr. Milton.—Coins from Michigan.

Professor Mitchell.—Reptiles, fishes and mammals from Tennessee.

Carlton R. Moore.—Deformed antlers of *Cervus virginianus.*

W. Moss.—Specimens of *Scarabæus tityus* from near Washington.

Dr. J. S. Newberry.—Minerals, fossil fishes, and reptiles from Ohio, skull of beaver from Lake Superior, skins of cinnamon bear, black bear, and young grizzlis from Oregon.

Dr. Newcomb.—100 species and 40 varieties of *Achatinella* from the Sandwich Islands.

Judge C. Newton.—*Arvicola* and *Hesperomys* in alcohol from Ohio.

New Orleans Academy of Natural Sciences.—One keg of serpents, and skins of squirrels from New Orleans.

Dr. Nichols.—Racoon from California.

John E. Nitchie.—Box minerals (*Lead ores*) from Shelburne, New Hampshire.

Lieutenant Nugen, U. S. A.—Skins of mountain goat from Cascade mountains, Oregon.

B. F. Odell.—Box with skins of mammals, lynx, rabbit, &c., from Iowa.

Captain Page, U. S. N.—Skin of ant-eater and goat, tank of alcoholic specimens, 4 bales plants from Paraguay, box birds, keg containing skin of Jaguar, *Myopotamus*, and armadillo from the Salado river, Paraguay.

Edward Palmer.—Reptiles, fishes and insects from Paraguay.

J. T. K. Plant.—Shells and miscellanea from Washington.

Professor Poey.—*Solenodon paradoxa.* Skull of *Capromys*, *Emys decussata*, and *rugosa*, from Cuba.

Captain Pope, U. S. A.—14 boxes of collections in all departments of natural history from the Llano Estacado, of Texas.

J. P. Postell.—Skins and skulls, mammals, shells, from Georgia.

J. W. Raymond.—Living plant, *Espirito santo*, from Panama. Large grasshopper from Aspinwall.

Peter Reid.—Portions of three specimens, *Tamias striatus*, from New York.

J. L. Reynolds.—*Menobranchus*, from Portage Lake.

Dr. J. L. Riddel.—Skin of *Sciurus magnicaudatus* from Missouri.

Captain Rodgers, U. S. N.—20 boxes, 9 kegs, one bale natural history collections from the Pacific coast.

Alexander P. Ross.—Slab sandstone from Pictou, Nova Scotia.

Joseph Rowell.—Box of shells, sloth and reptiles in alcohol, from Panama.

E. Samuels.—Birds, mammals, skeletons, plants, reptiles, and fishes, from Petaluma, California.

Mr. Savery.—Specimens of birds and mammals from Florida. (Deposited in part.)

Dr. B. F. Shumard.—*Salamandra glutinosa* from Missouri.

Dr. J. M. Skues.—Skin *Lepus glacialis* from Newfoundland.

J. W. Smith —Crustacea, and young rabbits from Florida.

W. A. Smith.—Two Iguanas from Nicaragua.

William Spence.—Large slab with coal fossils from Coalport, Ohio.

Dr. H. H. Stabb.—Two polar hares, 4 ptarmigans, 1 pine grosbeak, in flesh, from Newfoundland.

J. Stauffer.—Bottle of reptiles from Lancaster county, Pennsylvania.

Dr. C. W. Stevens.—Skull of grizzly bear from upper Missouri. (Deposited.)

Captain Stone.—Shells from near Santa Barbara, California.

Dr. Swift, U. S. A.—Dried plants, reptiles, insects, skins of birds, five mammals, sediments of rivers, from Fort Chadbourne, Texas.

Dr. George Suckley, U. S. A.—2 boxes mammals, birds, reptiles, fishes, and insects from Steilacoom; box of shells, skins, birds, mammals, from Panama and San Francisco.

A. S. Taylor.—Specimens of sediments, insects, reptiles, and fishes, gophers and minerals from Monterey, California.

Miss Helen Teunison.—Reptiles, fishes, and mammals, from Monticello, Mississippi.

J. F. Thickstun.—(For the institution of Natural History, Meadville, Pennsylvania.) Can mammals and reptiles in alcohol, box minerals, from Meadville, Pennsylvania.

Major G. H. Thomas, and Lieutenant Dubarry, U. S. A.—12 jars mammals and reptiles, one Phyllostome bat from Fort Yuma, California.

Professor Z. Thompson.—Specimens in alcohol of small mammalia from Burlington, Vermont.

Dr. D. Tompkins.—Perforated stones, used by Indian in games. From the banks of the Roanoke river.

Lieutenant W. P. Trowbridge U. S. A.—Skins of birds and mammals, can of fishes, from San Miguel, California; skeleton of sea lion from San Francisco.

N. Trübner.—280 microscopic slides of insects prepared by A. Heeger, Vienna.

Colonel Tuley.—Fresh skin of *Cervus dama*, (Fallow deer,) from Clark county, Virginia.

Dr Thomas T. Turner.—Cretaceous fossils from Nanaimo, gulf of Georgia, Vancouver's island.

Dr. Vollum, U. S. A.—Plants from Fort Belknap, Texas.

Rev. L. Vortisch.—Ancient German antiquities from Saxony.

M. Walker.—Jar reptiles and insects from Nebraska.

H. Mactier Warfield.—100 specimens of birds from Australia, *Ornithorhynchus* and *Petaurus*.

Lieutenant G. K. Warren, U. S. A.—48 boxes, collections in all departments of natural history, from the upper Missouri.

Mr. Watson.—Miscellaneous bones and part of skeleton of horse from Nebraska.

David Welsh.— Jaws of *Myliobatis* and gophers from Florida.

A. White.—Specimens of filterings and sediments for microscopic examination from Cazenova, New York.

John R. Willis.—Box of shells from vicinity of Halifax, Nova Scotia.

Mr. Wilson.—Specimens of vegetable fibre from Jamaica.

Dr. D. D. Wilson through *Dr. J. S. Newberry.*—Coal plants and fossil remains, from Missouri.

Dr. S. N. Wilson.—Skins, mammals, alcoholic specimens, and shells, living terrapins, from Georgia.

W. S. Wood.—See Bryan.

Charles Wright.—Seeds and dried plants, 12 jars reptiles, and insects from Nicaragua.

G. Würdemann.—Shells, eggs, and alcoholic specimens from Florida.

Washington Market.—*Sargus ovis* from Norfolk. Living *Emys rubriventris*, young sturgeon, fresh white fronted goose, muskrat, *Fuligula collaris*, from Potomac river.

Ed. C. Younger.—Reptiles from Washington.

Unknown.—Box of European birds.

——?.—Fishes from Puget's sound.

——?.—Box water-worn pebbles.

LIST OF METEOROLOGICAL STATIONS AND OBSERVERS

FOR THE YEAR 1856.

NOVA SCOTIA AND CANADA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Hall, Dr. A.	Montreal		45 30	73 36	57
Stuart, A. P. S.	Wolfville	Horton N. S.	45 06	64 25	95
Smallwood, Dr. Chas.	St. Martin	Laval	45 32	73 36	118
Magnetic Observatory	Toronto		43 39	79 21	108

MAINE.

Barrows, Geo. B.	Fryeburg	Oxford	44 03	71 00	
Bell, John J	Carmel	Penobscot	44 47	69 00	175
Dana, W. D.	Perry	Washington	45 00	67 06	100
Eveleth, Sam'l A.	Windham	Cumberland	43 49	70 17	
Gardiner, R. H.	Gardiner	Kennebec	44 11	69 46	90
Guptill, G. W.	Cornishville	York	43 40	70 44	800
Parker, J. D.	Steuben	Washington	44 44	67 58	50
Willis, Henry	Portland	Cumberland	43 39	70 15	87
Wilbur, Benj. F.	Monson	Piscataquis			

NEW HAMPSHIRE.

Bell, Sam'l N	Manchester	Hillsborough	42 59	71 28	300
Brown, B. Gould	Stratford	Coos	44 08	71 34	1,000
Hanscam, R. F.	North Barnstead.	Belknap	43 38	71 27	
Mack, R. C	Londonderry	Rockingham	42 53	71 20	
Odell, Fletcher	Shelbourne	Coos	44 23	71 06	
Prescott, Dr. Wm.	Concord	Merrimack	43 12	71 29	374
Purmort, Nath	West Enfield	Grafton	43 30	72 00	
Sawyer, Geo. B.	Salmon Falls	Strafford	43 12	71 00	
Sawyer, Henry E.	Great Falls	Strafford	43 17	70 52	

VERMONT.

Bliss, Geo.	Shelburne	Chittenden	44 23	73 00	150
Bliss, L. W.	Bradford	Orange	43 55	72 15	
Buckland, David.	Brandon	Rutland	43 45	73 00	
Jackman, A.	Norwich	Windsor	43 42	72 20	
Paddock, Jas. A.	Craftsbury	Orleans	44 40	72 30	1,100

MASSACHUSETTS.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Allin, Lucius	Springfield	Hampden	42 06	72 35	199
Bacon, William	Richmond	Berkshire	42 23	73 20	1,190
Bond, Prof. W. C	Cambridge	Middlesex	42 22	71 07	--------
Brooks, John	Princeton	Worcester	42 28	71 53	1,113
Darling, L. A	Bridgewater	Plymouth	42 00	71 00	142
Davis, Rev. E	Westfield	Hampden	42 06	72 48	--------
Holcomb, Amasa	Southwick	Hampden	42 02	72 10	265
MaGee, Irving; Wilson, L	Williamstown	Berkshire	42 43	73 13	720
Metcalf, John Geo	Mendon	Worcester	42 06	72 33	--------
Mitchell, Hon. Wm	Nantucket	Nantucket	41 16	70 06	30
Perkins, Dr. H C	Newburyport	Essex	42 47	70 52	46
Rice, Henry	North Attleboro'	Bristol	41 59	71 22	175
Rodman, Sam'l	New Bedford	Bristol	41 39	70 56	90
Rice, Frank H.; Smith, Edw. A; Sargent, John S	Worcester	Worcester	42 16	71 48	536
Snell, Prof. E. S	Amherst	Hampshire	42 22	72 34	267
Schlegel, Albert	Taunton	Bristol	41 49	71 09	--------
Tirrell, Dr. N. Quincy	Weymouth	Norfolk	43 00	71 00	150

RHODE ISLAND.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Arnold, E. G	Acquidueset	Washington	--------	--------	--------
Caswell, Prof. A	Providence	Providence	41 49	71 25	120

CONNECTICUT.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Edwards, Rev. T.	New London	New London	41 21	72 12	90
Harrison, Benj. F	Wallingford	New Haven	41 26	72 50	133
Hull, Aaron B	Georgetown	Fairfield	41 15	73 00	300
Hunt, D	Pomfret	Windham	41 52	72 23	596
Rankin, Jas	Saybrook	Middlesex	41 18	72 20	10
Scholfield, N	Norwich	New London	41 32	72 03	--------
Yeomans, W. H	Columbia	Tolland	42 20	72 46	--------

NEW YORK.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Aubin, John	Fordham	Westchester	40 54	--------	147
Alba, Dr. E. M	Angelica	Alleghany	42 15	78 01	1,500
Arden, Thos. B	Beverly	Putnam	41 22	72 12	180
Bowman, John	Baldwinsville	Onondaga	43 04	76 41	--------
Breed, J. Everett	Smithville	Jefferson	44 00	76 01	--------
Byram, E. N	Sag Harbor	Suffolk	41 00	72 20	40
Chickering, J. W	Ovid	Seneca	42 41	76 52	--------
Dayton, E. A	Madrid	St. Lawrence	44 43	75 33	280
Denning, W. H	Fishkill Landing	Dutchess	41 34	74 18	42
Dewey, Prof. Chester	Rochester	Monroe	43 08	77 51	516

NEW YORK—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Felt, John	Liberty	Sullivan	41 45	74 45	1,474
French, John R	Mexico	Oswego	43 27	76 14	423
Gorton, J. S	Westfarms	Westchester	40 53		150
Greene, Prof. Dascom	Troy	Rensselaer	42 44		
Guest, W. E	Ogdensburgh	St. Lawrence	44 43	75 26	
House, J. Carroll	Lowville	Lewis	43 46	75 38	
Johnson, E W	Canton	St. Lawrence	44 38	75 15	304
Kendall, John F	Pompey Hill	Onondaga			1,737
Lefferts, John	Lodi	Seneca	42 37	76 53	
Lobdell, Mrs. M. J	North Salem	Westchester	41 20	73 38	361
Malcolm, Wm. S	Oswego	Oswego	43 28	77 34	232
Morehouse, A. W	Spencertown	Columbia	42 19	73 41	800
Morris, Prof. O. W	New York	New York	40 43	74 05	159
Norton, J. H	Plainville	Onondaga	43 00		
Pernot, Claudius	Fordham	Westchester	40 54		147
Pratt, W. C	Rochester	Monroe	43 08	77 51	516
Reed, Edward C	Homer	Courtland	42 38	76 11	1,100
Reid, Peter	Lake P. O	Washington	43 15	73 33	
Riker, Walter H	Saratoga	Saratoga	42 00	74 00	960
Root, Prof. O	Clinton	Oneida	43 00	75 20	500
Sanger, Dr. W. W	Blackwells Island		40 45	73 57	29
Sartwell, Dr. H. P	Penn Yan	Yates	42 42		740
Spooner, Stillman	Wampsville	Madison	43 04	75 50	500
Smith, J. Metcalf	McGrawville	Courtland	42 34		
Taylor, Jos. W	Plattsburgh	Clinton	44 40		156
Tourtellot, Dr. L. A	Utica	Oneida	43 07	75 15	500
Van Kleek, Rev. R. D	Flatbush	Kings	40 37	74 01	54
White, Aaron	Cazenovia	Madison	42 55	75 46	1,260
Williams, Dr. P. O	Watertown	Jefferson	43 56	75 55	
Wilson, Rev. W. D	Geneva	Ontario	42 53	77 02	567
Woodward, Lewis	West Concord	Erie	43 00	79 00	2,000
Yale, Walter D	Houseville	Lewis	43 40	75 32	

NEW JERSEY.

Cooke, R. L	Bloomfield	Essex	40 49	74 11	120
Dodd, C. M	Salem	Salem	39 34	75 27	
Frost, Adolph; Schmidt, Dr. E. R	Burlington	Burlington	40 00	75 12	26
Whitehead, W. A	Newark	Essex	40 45	74 10	30

PENNSYLVANIA.

Brown, Samuel	Bedford	Bedford	40 01	78 30	
Baird, John H	Tarentum	Alleghany	40 37		950
Brickenstein, H. A	Nazareth	Northampton	40 43	75 21	
Brugger, Samuel	Fleming	Centre	40 55	77 53	780
Chorpenning, Dr. F	Somerset	Somerset	40 02	79 02	1,997
Darlington, Fenelon	Pocopson	Chester	39 54	75 37	218
Edwards, Joseph	Chromedale	Delaware	39 55	75 25	196
Eggert, John	Berwick	Columbia	41 05	76 15	
Friel, P	Shamokin	Northumberland	40 45		700
Hance, Ebenezer	Morrisville	Bucks	40 12	74 53	30
Heisely, Dr. John	Harrisburg	Dauphin	40 16	76 50	

PENNSYLVANIA—Continued.

Name of observer.	Station.	County.	N. lat. ° ′	W. long. ° ′	Height. *Feet.*
Hobbs, O. T.	Randolph	Crawford	41 28	80 10	1,720
Jacobs, Rev. M.	Gettysburg	Adams	39 51	77 15	
James, Charles S	Lewisburg	Union	40 58	76 58	
Kirkpatrick, Prof. J. A.	Philadelphia	Philadelphia	39 57	75 11	60
Kohler, Edward	North Whitehall	Lehigh	40 40		250
Ralston, Rev. J. Grier	Norristown	Montgomery	40 08	75 19	153
Schreiner, Francis	Moss Grove	Crawford	41 40	79 51	
Scriba, Victor	Troy Hill	Alleghany			
Smith, Prof. Wm.	Canonsburg	Washington	40 25	80 07	
Swift, Dr. Paul	West Haverford	Delaware	40 00	75 21	
Thickstun, J. F	Meadville	Crawford	41 39	80 11	1,088
Wilson, Prof. W. C.	Carlisle	Cumberland	40 12	77 11	500
Wilson, W. W.	Pittsburgh	Alleghany	40 32	80 02	1,026

DELAWARE.

Crawford, W. A. Craven, Thos. J. Martin, R. A.	Newark	New Castle	39 38	75 47	120

MARYLAND.

Baer, Miss H. M.	Shellman Hills	Carroll	39 23	76 57	700
Goodman, W. R.	Annapolis	Anne Arundel	38 58	76 29	
Hanshaw, Henry E.	Frederick	Frederick	39 24	77 18	
Lowndes, B. O	Bladensburg	Prince George	38 57	76 58	
Pearce, James A., jr.	Chestertown	Kent	39 14	76 02	
Stagg, T. G	Ridge	St. Mary's			
Zumbrock, A., M. D.	Annapolis	Anne Arundel	38 58	76 29	34

VIRGINIA.

Astrop, Lieut. R. F.	Crichton's Store	Brunswick	36 40	77 46	
Beckwith, T. S., M. D.	Garysville	Prince George			
Clarke, James T.	Mount Solon	Augusta			
Couch, Samuel	Ashland	Putnam	38 38	81 57	
Ellis, D. H.	Crack Whip	Hardy	39 30		
Fauntleroy, H. H.	Montrose	Westmoreland	38 07	76 54	200
Hallowell, Benjamin	Alexandria	Alexandria	38 48	77 01	56
Hoff, Josiah W.	Wirt C. H.	Wirt	35 05		
Hotchkiss, Jed	Mossy Creek	Augusta	39 35	78 30	
Kendall, James E.	Charleston	Jefferson	38 20	81 21	
Kownslar, Miss Ellen	Berryville	Clark	39 09	78 00	575
Marvin, John W.	Winchester	Frederick	39 15	78 10	
Patton, Thomas, M. D.	Lewisburg	Greenbrier	38 00	80 00	2,000
Purdie, John R.	Smithfield	Isle of Wight	36 50	76 41	100
Quincy, W C.	West Union	Doddridge	39 15	81 00	1,100
Ruffin, Julian C.	Ruthven	Prince George	37 21	77 33	
Ruffner, David L	Kanawha	Kanawha	37 53		
Skeen, William	Huntersville	Pocahontas	39 30		2,640
Webster, Prof. N. B.	Portsmouth	Norfolk	36 50	76 19	34

NORTH CAROLINA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
McDowell, Rev. A	Murfreesboro'	Hertford	36 30		
Moore, Geo. F., M. D.	Gaston	Northampton			
Morelle, Daniel	Goldsboro'	Wayne			
Phillips, Prof. James	Chapel Hill	Orange	35 54	79 17	

SOUTH CAROLINA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Fuller, E N., M. D	Edisto Island	Colleton	32 34	80 18	23
Glennie, Rev. Alex'r	Waccaman	All Saints	33 40	79 17	20
Johnson, Joseph, M.D.	Charleston	Charleston	32 46	80 00	30
Ravenel, H. W	Aiken	Barnwell	33 32	81 34	565
White, Prof. J. B	Columbia	Richland	33 57	81 07	
Young, J. A., M. D	Camden	Kershaw	34 17	80 33	275

GEORGIA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Anderson, Jas., M. D	The Rock	Upson	32 52	84 23	833
Gibson, R. P	Whitemarsh Is'd.	Savannah	32 04	81 05	
Haines, William	Augusta	Richmond	33 28	81 54	
Pendleton, E. M., M.D.	Sparta	Hancock	33 17	83 09	550
Posey, John F	Savannah	Chatham	32 05	81 07	42

FLORIDA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Bailey, James B	Garrisville	Alachua	29 35	82 26	
Baldwin, A. G., M. D	Jacksonville	Duval	30 30	82 00	13
Dennis, W. C	Salt Ponds	Key West	24 33	81 48	
Fry, Lieut. Joseph	Pensacola	Escambia	30 20	87 16	12
Mauran, P. B., M. D	St. Augustine	St. John's	29 48	81 35	8
Steele, Aug	Cedar Keys	Levy	29 07	83 02	12

ALABAMA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Alison, H. L., M D	Carlowville	Dallas	32 10	87 15	300
Darby, Prof. John	Auburn	Macon	33 37	88 03	821
Tutwiler, H	Greene Springs	Greene	32 50	87 46	
Waller, Robert B	Greensboro'	Greene	32 30	87 10	350

MISSISSIPPI.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
Elliott, Prof. J. Boyd	Port Gibson	Claiborne	31 50	91 00	500
Harper, Dr. L	Oxford	Lafayette	34 20	89 25	338
Lull, James S	Columbus	Lowndes	33 30	88 29	227
Smith, J. Edwards	Natchez	Adams	31 34	91 24	

LOUISIANA.

Name of observer.	Station.	County.	N. lat.	W. long	Height.
			° ′	° ′	*Feet.*
Barton, E. H., M. D	New Orleans	Orleans	29 57	90 00	
Kilpatrick, A. R., M. D.	Trinity.	Catahoula	31 30	91 46	108
Merrill, Edward, M. D.	Trinity.	Catahoula			
Taylor, Lewes, B.	New Orleans	Orleans.	29 57	90 00	

TEXAS.

Brightman, John C.	Helena.	Karnes			
Forke, J. L.	New Wied	Comal.	29 42	98 15	
Jennings, S. K., M. D	Austin.	Travis.	30 20	97 46	
Rucker, B. H.	Washington.	Washington			

TENNESSEE.

Bean, Jas. B.	Walnut Grove	Greene	36 00	82 53	1,350
Griswold, Prof. T. L	Knoxville	Knox	35 59	83 50	1,000
Stewart, William M.	Glenwood	Montgomery	36 28	87 13	481

KENTUCKY.

Beatty, O.	Danville	Boyle	37 40	84 30	950
Ray, L. G., M. D.	Paris	Bourbon	38 16	84 07	
Savage, Geo. S., M. D.	Millersburg	Bourbon	38 40	84 27	804
Swain, John, M. D.	Ballardsville	Oldham	38 26	85 30	

OHIO.

Bennett, Henry	Collingwood	Lucas			
Binkerd, J. S.	Germantown	Montgomery	39 39	84 11	
Bosworth, R. S.	College Hill.	Hamilton	39 19	84 25	800
Cunningham, Miss A.	Unionville	Lake	41 52	81 00	650
Dayton, L. M.	Zanesville	Muskingum	39 58	82 19	
Fairchild, J. H.	Oberlin.	Loraine	41 20	82 15	800
Fischer, Jas. C., M. D.	Dayton.	Montgomery	39 44	89 11	
Groneweg, Lewis	Germantown.	Montgomery	39 30	84 11	720
Hannaford, Ebenezer	Cheviot	Hamilton	39 07	84 34	
Harper, George W.	Cincinnati	Hamilton	39 06	84 27	150
Herrick, James D.	Jefferson	Ashtabula	42 00	81 00	
Hillier, Spencer L.	Hiram	Portage	41 20	81 15	675
Hollenbeck, F. & D. K.	Perrysburg	Wood	41 39	83 40	
Holston, J. G. F., M. D.	Zanesville	Muskingum	39 58	82 29	700
Hyde, G. A.	Cleveland	Cuyahoga	41 30	81 40	665
Ingram, John, M. D	Savannah.	Ashland	41 12	82 31	
Livezay, G. W.	Gallipolis.	Gallia	39 00	82 01	520
Luther, S. M.	Hiram	Portage	41 20	81 15	675
Mathews, J. McD.	Hillsboro'	Highland	39 13	83 30	1,000

OHIO—Continued.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
McCarty, H. D.	West Bedford	Coshocton	40 18	82 01	
Poe, James H.	Portsmouth	Scioto	38 50	82 49	468
Sanford, Prof. S. N.	Granville	Licking	40 03	82 34	995
Schenck, W. L., M. D.	Franklin	Warren			
Shaw, Joseph	Bellefontaine	Logan	40 21	83 40	
Williams, Prof. M. G.	Urbana	Champaign	40 06	83 43	1,015

MICHIGAN.

Andrews, Seth L. & G. P.	Romeo	Macomb	42 44	83 00	730
Campbell, Wm. M.	Battle Creek	Calhoun	42 20	85 10	
Currier, A. O.	Grand Rapids	Kent	43 00	86 00	752
Duffield, Rev. Geo.	Detroit	Wayne	42 24	82 58	620
Goff, Mrs. M. A.	Eagle River	Houghton			
Strang, James J.	St. James	Beaver Island	45 44	85 27	598
Streng, L H.	Saugatuck	Alleghan	40 30	85 50	
Walker, Mrs. O. C.	Cooper	Kalamazoo	42 40	85 31	
Whelpley, Miss H.	Monroe	Monroe	41 56	83 22	590
Whittlesey, Chas. S.	Copper Falls		47 25	88 16	1,230
Winchell, Prof. A.	Ann Arbor	Washtenaw	42 16	83 44	891
Woodruff, Lum.	Ann Arbor	Washtenaw	42 16	83 30	850

INDIANA.

Barnes, C.	New Albany	Floyd			
Chappellsmith, John	New Harmony	Posey	38 08	87 50	320
Moore, Joseph	Richmond	Wayne	39 47	84 47	800
Smith, Hamilton	Cannelton	Perry			

ILLINOIS.

Babcock, E.	Riley	McHenry	42 08	88 33	650
Brendel, Fred., M. D.	Peoria	Peoria			
Eldredge, William V.	Brighton	Macoupin			
Grant, John	Manchester	Scott	39 33	90 34	683
Hall, Joel	Athens	Menard	39 52	89 56	
Harris, J. O., M. D.	Ottawa	La Salle	41 20	88 47	500
Hiscox, G. D.	Chicago	Cook	41 53	87 41	600
James, John, M. D.	Upper Alton	Madison	39 00	89 36	
Mead, S. B., M. D.	Augusta	Hancock	40 12	89 45	200
Rogers, O. P.	Marengo	McHenry	42 14	88 38	
Titze, Henry A.	West Salem	Edwards	38 30	88 00	
Whitaker, Benjamin	Warsaw	Hancock			

MISSOURI.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Chandler, Chas. Q., M. D.	Rockport	Boone	38 55	92 38	--------
Duffield, Edw., M. D.	Hannibal	Marion	39 45	91 00	--------
Engelmann, Geo., M. D.	St. Louis	St. Louis	38 37	90 16	481
Wislizenus, A., M. D.	St. Louis	"	--------	--------	461

IOWA.

Beal, Dexter	Fairbanks	Buchanan	42 45	87 16	--------
Bidwell, E. C., M. D.	Quasqueton	Buchanan	42 23	91 43	890
Connel, Townsend M.	Pleasant Plain	Jefferson	--------	--------	--------
Fairall, Hermann H.	Iowa City	Johnson	--------	--------	--------
Fory, John C.	Bellevue	Jackson	--------	--------	--------
Goss, Geo. C. & Wm. K.	Border Plains	Webster	--------	--------	--------
McCready, Daniel	Fort Madison	Lee	40 37	91 28	--------
Parker, Nathan H.	Clinton	Clinton	--------	--------	--------
Parvin, T. S.	Muscatine	Muscatine	41 26	91 05	586
Scheeper, E. H. A.	Pella	Marion	41 30	72 55	730
Shaffer, J. M.	Fairfield	Jefferson	--------	--------	--------

WISCONSIN.

Bean, Prof. S. A.	Waukesha	Waukesha	--------	--------	--------
Breed, J. Everett	New London	Waupacca	--------	--------	--------
Durham, W. J.	Racine	Racine	42 49	87 40	--------
Himoe, John E.	Norway	Racine	42 50	88 10	--------
Loring, C. jr. } Washington, L. & R. }	Superior	Douglas	46 38	92 03	658
Mason, Prof. R. Z.	Appleton	Outagamie	44 10	88 35	800
Park, Rev. Roswell	Racine	Racine	42 49	87 40	--------
Pickard, J. L., M. D.	Platteville	Grant	42 45	90 00	--------
Pomeroy, F. C.	Milwaukie	Milwaukie	43 04	87 59	658
Porter, Prof. Wm.	Beloit	Rock	42 30	89 04	750
Seibert, Samuel R.	Cascade Valley	Buffalo	44 30	92 00	--------
Schue, A., M. D.	Madison	Dane	43 05	89 25	892
Sterling, Prof. J. W.	Madison	Dane	43 05	89 25	892
Winkler, C., M. D.	Milwaukie	Milwaukie	43 04	87 57	593
Willard, J. F.	Janesville	Rock	42 42	89 91	768

CALIFORNIA.

Ayres, W. O., M. D.	San Francisco	San Francisco	37 48	122 23	115
Logan, Thos. M., M. D.	Sacramento	Sacramento	38 35	121 40	49
Reid, R. K., M. D.	Stockton	San Joaquin	--------	--------	--------

MINNESOTA.

Name of observer.	Station.	County.	N. lat.	W. long.	Height.
			° ′	° ′	*Feet.*
Brooks, Rev. Jabez	Red Wing	Goodhue	44 34	92 30	
Garrison, O. E	Princeton	Benton	45 50		
Odell, Rev. B. F	Cass Lake Mission				
Riggs, S. R	Hazlewood				

HUDSON'S BAY TERRITORY.

Gunn, Donald	Red River Settlement.		50 06	97 00	853

MEXICO.

Ervendberg, Prof. L. C.	Mexico		19 30	99 00	7,665

VENEZUELA.

Fendler, Aug	Tovar	Aragua Province	10 26	67 20	6,500

SURINAM.

Hering, C. T	Catharina Sophia				

SANDWICH ISLANDS.

Hillebrand, Wm., M.D.	Honolulu		21 19	157 52	

JAMAICA.

Sawkins, James G	Up Park Camp				

TRINIDAD.

Geological Surveyors	Port of Spain		10 39	61 34	16

PERSIA.

Rev. Mr. Stoddard	Oroomiah				

REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee submit the following report of the state of the finances of the Smithsonian Institution, the expenditures during the year 1856, and an estimate of receipts and appropriations for 1857.

The whole sum appropriated for the current expenses of the Institution for the year 1856, including the remaining payment on the building, was thirty-nine thousand dollars. The actual expenditures for the several items do not materially differ from those specified in the estimate submitted by the committee and adopted by the Board. The whole sum expended was $38,158 90, which is less than the amount appropriated by $841 10.

A committee was appointed February 24, 1855, consisting of Messrs. English, Pearce, and Mason, to consider the best means of investing the extra fund, Mr. Corcoran having signified his intention to relinquish the charge of the money deposited with him. After due consultation, the committee concluded to recommend the purchase of State stocks. This being agreed to by the Board, at a subsequent meeting the Secretary was instructed to make the purchase under the direction of the Finance Committee. An account of the transaction under this resolution is given in the report of the Hon. Mr. English of that committee.

It will be recollected that the extra fund amounted to one hundred and twenty-five thousand dollars, and from the report of Mr. English it will be seen that of this sum one hundred and nineteen thousand four hundred dollars have been expended in the purchase of State stocks; that six hundred dollars remain in the hands of Messrs. Riggs & Co.; and that five thousand dollars of that fund, applied in 1855 to the payments on the building, is now in the treasury. There is, therefore, five thousand six hundred dollars of the extra fund uninvested. It is, however, not advisable to invest this immediately, because the half-yearly income of the Institution is not receivable until the first of July, and it is necessary to retain a sufficient sum in the treasury to meet the payments for paper, printing, &c., for the next volume of Contributions, which cannot be postponed.

The following is a general statement of the fund:

The whole amount of the Smithsonian bequest deposited in the treasury of the United States (from which an annual income, at 6 per cent., of $30,910 14 is derived) is		$515,169 00
Extra fund from unexpended income, now invested in State stocks, yielding an annual interest of $7,380	$119,400 00	
Extra fund deposited with Riggs & Co., to be invested	600 00	

Amount in the treasury, being part of the extra fund of accumulated interest, designed to be invested, and which, with the above sums of $119,400 and $600, will make the amount $125,000, appropriated for the increase of the permanent fund	$5,000 00	
		$125,000 00
Balance in the hands of the treasurer January 1, 1857, $7,164 32, from which deduct the $5,000 belonging to the extra fund		2,164 32
		$642,333 32

The following is a general view of the receipts and expenditures during the year 1856:

RECEIPTS.

Balance in the hands of the treasurer January 1, 1856, of which $5,000 belongs to the extra fund*		$8,189 75	
Interest on the original fund ($515,169) for 1856		30,910 14	
Interest on the extra fund from Corcoran & Riggs, while on deposit	$2,533 33		
Interest on the extra fund since investment in State bonds	3,690 00		
		6,223 33	
			$45,323 22

EXPENDITURES.

For building, furniture, fixtures, &c.	$7,891 04	
For items common to the objects of the Institution	12,859 28	
For publications, researches, and lectures	7,876 23	
For library, museum, and gallery of art	9,532 35	
		$38,158 90
Balance in the hands of the treasurer January 1, 1857, of which $5,000 belongs to the extra fund		7,164 32

* Reduced nine cents, to correct an error in last statement.

The following is a detailed statement of the expenditures during 1856:

BUILDING, FURNITURE, FIXTURES, ETC.

Pay on contracts, &c	$6,036 38	
Repairs and miscellaneous incidentals to building	1,359 23	
Furniture and fixtures for uses in common	198 83	
Furniture and fixtures for library	163 16	
Furniture and fixtures for museum	38 14	
Magnetic observatory	48 80	
Grounds	46 50	
		$7,891 04

GENERAL EXPENSES.

Meetings of Board and committees	369 50	
Lighting and heating	1,303 92	
Postage	696 76	
Transportation and exchange	1,134 29	
Stationery	109 67	
General printing	383 25	
Apparatus	739 18	
Laboratory	629 91	
Incidentals, general	883 92	
Salaries—Secretary	3,499 92	
Chief clerk	1,200 00	
Book-keeper	200 00	
Janitor	399 96	
Watchman	372 00	
Laborers	636 00	
Messenger	192 00	
Extra clerks	109 00	
		12,859 28

PUBLICATIONS, RESEARCHES, AND LECTURES.

Smithsonian Contributions to Knowledge	4,355 38	
Reports on the progress of knowledge	75 50	
Other publications	158 20	
Meteorology	2,279 90	
Investigations, computations, and researches	142 75	
Lectures:		
Pay of lecturers	835 00	
Incidentals to lectures	29 50	
		7,876 23

LIBRARY, MUSEUM, AND GALLERY OF ART.

Library:		
Cost of books	$3,692 05	
Pay of assistants	1,728 00	
Transportation	451 39	
Incidentals	152 50	
Museum:		
Salary of assistant secretary	1,999 92	
Explorations	158 25	
Collections	220 08	
Alcohol, glass jars, &c	352 64	
Transportation	349 96	
Assistance and labor	327 00	
Gallery of art	100 56	
		$9,532 35
		$38,158 90

The committee present the following estimates of receipts and expenditures for the year 1857:

RECEIPTS.

Balance in the hands of the treasurer January 1, 1857, (exclusive of $5,000 belonging to extra fund)	$2,164 32	
Interest on the original fund ($515,169) for 1857	30,910 14	
Interest on the extra fund invested in State stocks	7,380 00	
		$40,454 46

EXPENDITURES.

Building, furniture, fixtures, &c.:		
Repairs, additions, and miscellaneous incidentals	$1,000 00	
Furniture and fixtures for uses in common	600 00	
Furniture and fixtures for library	350 00	
Furniture and fixtures for museum	200 00	
Magnetic observatory	60 00	
		$2,210 00

GENERAL EXPENSES.

Meetings of Board and committees	$250 00	
Lighting and heating	1,300 00	
Postage	550 00	
Transportation and exchange	1,600 00	

Stationery	$120 00	
General printing	200 00	
Apparatus	500 00	
Laboratory	300 00	
Incidentals, general	850 00	
Salaries—Secretary	3,500 00	
Chief clerk	1,200 00	
Book-keeper	200 00	
Janitor	400 00	
Watchman	400 00	
Laborers	700 00	
Extra clerks	500 00	
		$12,570 00

PUBLICATIONS, RESEARCHES, AND LECTURES.

Smithsonian Contributions to Knowledge	$6,000 00	
Reports on the progress of knowledge	500 00	
Other publications	500 00	
Meteorology	3,000 00	
Investigations, computations, and researches	620 00	
Lectures:		
Pay of lecturers	900 00	
Incidentals	300 00	
		$11,820 00

LIBRARY, MUSEUM, AND GALLERY OF ART.

Cost of books	$1,000 00	
Pay of assistants	2,000 00	
Transportation for library	300 00	
Incidentals for library	200 00	
Museum, salaries	2,000 00	
Explorations	200 00	
Collections	200 00	
Alcohol, glass jars, &c	300 00	
Transportation for museum	350 00	
Assistance and labor for museum	600 00	
Gallery of art	250 00	
		$7,400 00
		$34,000 00

From this it will be seen that the estimates of expenditure for the year 1857 are six thousand dollars less than the receipts for the same time. It is advisable thus to limit the expenditures for the present year, not merely because it is easier to expand the operations of the Institution than to contract them, but because, as the revenue is payable semi-annually and the accounts must be paid whenever presented, the

treasurer has sometimes been obliged to overdraw on the bankers of the Institution, whereas the six thousand dollars, reserved from appropriation and left in the treasury during the present year, will enable the Secretary and Executive Committee to defray all expenditures without subjecting the Institution to charges for interest on overdrafts.

The committee report, also, that they have examined all the accounts and vouchers and compared them with the books, and find them all correct.

Respectfully submitted:

J. A. PEARCE,
A. D. BACHE,
J. G. TOTTEN,
Executive Committee.

REPORT OF THE BUILDING COMMITTEE.

The Building Committee of the Smithsonian Institution present the following report of their operations and expenditures during the year 1856.

At the date of the last report of the committee, the building was considered finished, but it has been thought best, during the past year, to make a series of additional drains from the principal windows and doors of the basement to the main sewer, which passes under ground from the extreme east end of the building along the middle of the cellar to the west end of the principal edifice, and thence through the grounds to another sewer emptying into the canal. The length of these additional drains in the aggregate amounts to about seven hundred and thirty-three feet. They were necessary to carry off the water which descends through the spouts from the roof, and the rain which falls into the sunken spaces exterior to the windows and doors of the basement. They are constructed of brick, and supplied in each case with a trap to prevent the escape of offensive effluvia.

During the last summer, according to the statement of the Secretary, a very disagreeable odor was perceived in the east wing of the building, which was readily traced to the main sewer. It was observed to be more intense at certain times than at others, and after considerable examination was found to depend on the tide wave of the Potomac, which enters the extreme mouth of the sewer, condenses the contained air, and forces it back to the extremity of the drains, where it escapes through the minute crevices of the encasing brick-work. The cause of the difficulty having been discovered, a remedy was readily suggested. This consisted in tapping the main drain before it reached the building, and erecting over the opening a chimney communicating with the exterior atmosphere. Through this the condensed air escapes, the internal pressure is relieved, and the disagreeable effluvium is no longer forced into the building.

The attention of the Building Committee has also been directed by the Secretary to the fact that, in the original plan of the edifice, it was intended to provide for the drainage in a manner differing from the present mode. For this purpose, three large cylindrical excavations were made in the ground, two on the front, and one in the rear of the building. They are each about nine feet in diameter, thirty feet deep, cased with brick, and covered with planks and earth. Fear has been expressed that the wooden coverings of these wells may decay, and that accidents may occur from the breaking through of carriages. The committee would, therefore, recommend that they be either filled up, or permanently secured by a dome of brick over each The latter plan is preferred, both on account of cheapness and the

fact that one of the excavations may hereafter be used as an ice-house, and the others for investigations connected with subterraneous temperature and other physical phenomena.

From the statement of the accounts given by the Executive Committee it will be seen that the following sums have been expended on the building, viz:

Pay on contracts, &c.	$6,036 38
Repairs and miscellaneous incidentals	1,359 23

The first item includes the amount paid the original contractor, Gilbert Cameron, to close his account, and also for the drains and other permanent additions to the building. The second item includes all the sums paid for work done on the roof, and for repairing and painting all the water-courses lined with tinned iron.

Respectfully submitted,

WM. H. ENGLISH,
JOSEPH HENRY,
Building Committee.

JOURNAL OF PROCEEDINGS

OF THE

BOARD OF REGENTS

OF

THE SMITHSONIAN INSTITUTION.

JUNE 18, 1856.

The Board of Regents met this day at 11 o'clock, in the hall of the Institution.

Present: Hon. R. B. Taney, Chancellor, Hon. J. A. Pearce, W. H. English, H. Warner, A. D. Bache, Wm. B. Magruder, and the Secretary, and by special invitation Mr. W. W. Corcoran. The Secretary stated that Dr. W. B. Magruder, having been elected Mayor of the city of Washington, is *ex officio* a Regent of the Institution, and therefore takes his seat in the Board.

Mr. English, from the Finance Committee, made the following report.

The Committee on Finance charged by the resolution of March 8, 1855, with the duty of enquiring into and reporting upon the propriety and manner of permanently investing the money of the Institution now in the hands of Messrs. Corcoran and Riggs, respectfully report:

1st. That in the judgment of the committee the best disposition to make of said fund would be to add it to the funds of the Institution already in the treasury of the United States, and to that end, your committee recommend that application be made to Congrese for an act authorizing such addition.

2d. As the money is at present yielding the Institution no interest, your committee further recommend, that for the time being, and until favorable action can be procured by Congress in relation to receiving said extra fund into the United States treasury, the same be invested, under the direction of the Finance Committee, in the stocks and bonds of such sound interest paying States, and at such rates as the Board of Regents may select and determine.

All of which is respectfully submitted.

The following resolutions were offered:

Resolved, That the report of the Committee on Finance be concurred in, and that the Chancellor appoint a committee to make application to Congress for an act authorizing the receipt of the extra fund into the treasury of the United States.

And further be it resolved, That until such action by Congress can

be procured, the Committee on Finance invest said fund, in the name of the Regents of the Smithsonian Institution, in such bonds and stocks as are mentioned in the following table, and at such rates, including brokerage, as will not exceed one per cent. above the rates mentioned in said table, viz:

35,000 Virginia	6 per cent.	bonds	at 95	cents.
36,000 Pennsylvania	5 "	"	at 85	"
36,000 Indiana	5 "	"	at 85	"
36,000 Missouri	6 "	"	at 85	"

On motion of Dr. Magruder, the report of the committee was accepted, and the resolutions were adopted.

The Chancellor appointed Hon. J. A. Pearce, of the Senate, and Hon. H. Warner, of the House of Representatives, a committee to make application to Congress for an act authorizing the receipt of the extra fund into the treasury of the United States.

The Board then adjourned to meet at the call of the Secretary.

WEDNESDAY, JULY 9, 1856.

The Board of Regents met this day in the committee room of the Library of Congress.

Present: Hon. J. A. Pearce, James M. Mason, S. A. Douglas, W. H. English, H. Warner, A. D. Bache, and the Secretary.

The Secretary stated that Mr. Corcoran had informed him that he could not purchase the stocks directed to be bought by the Board at its last meeting at the prices limited by the resolution of June 18, 1856.

On motion of Dr. Magruder, it was resolved that the Secretary, under the direction of the Committee on Finance, be instructed to purchase the said stocks at the market rate, and if any of said stocks have advanced in price, the Secretary, under the instruction of said committee, may invest in other stocks at discretion.

The Board then adjourned *sine die.*

ELEVENTH ANNUAL SESSION.

JANUARY 21, 1857.

In accordance with a resolution of the Board of Regents of the Smithsonian Institution, fixing the time of the beginning of their annual meeting on the third Wednesday of January of each year, the Board met this day in the hall of the Institution.

Present: Hon. J. A. Pearce, Hon. W. H. English, Hon. B. Stanton, Professor Bache, and the Secretary.

No quorum being present, the Board adjourned to meet on Saturday, January 24, 1857, at 11 o'clock a. m.

JANUARY 24, 1857.

The Board met this day at 11 o'clock a. m.

Present: Hon James A. Pearce, Hon. S. A. Douglas, Hon. W. H. English, Hon. B. Stanton, Hon. George E. Badger, Hon. W. B. Magruder, Professor C. C. Felton, and the Secretary.

In the absence of the Chancellor Mr. Pearce was called to the chair.

The minutes of the meetings of June 18, July 9, 1856, and of January 21, 1857, were read and approved.

Hon. Mr. English, from the Committee on Finance, presented the following report.

The Committee on Finance, charged by resolutions of the Board of Regents with the duty of permanently investing the extra fund of the Institution, beg leave to report that, in accordance with the resolution of July 9, 1856, there have been purchased stocks and bonds of the States of Indiana, Virginia, and Tennessee, amounting in the aggregate to $135,500, and at a cost of $119,400, from which should be deducted the interest, accrued at date of purchase, say $1,000, leaving the nett cost to the Institution $118,400.

The annual interest upon these stocks and bonds amount to $7,380, whereas, the interest upon the purchase money, as heretofore invested, was but $5,920, making an annual gain to the Institution in the item of interest of $1,460.

For further and full particulars, the committee refer to the following report made to them by the Secretary of the Institution.

To the Committee on Finance of the Board of Regents of the Smithsonian Institution.

GENTLEMEN: In accordance with the resolution of the Board of Regents, adopted July 9th, 1856, authorizing the Secretary, under the direction of the Committee on Finance, to purchase State stocks for the Institution with the extra fund, I respectfully submit the following report:

With the assistance of the Hon. Mr. English, and under the direction of the Committee on Finance, there have been purchased,

INDIANA five per cent. bonds, amounting to..	$75,000 for	$63,000 00
and under the direction of the committee and through the agency of Messrs. Riggs & Co.		
VIRGINIA, six per cent. bonds, amounting to including commission, and also of	53,500 for	49,832 50
TENNESSEE six per cent bonds..................	7,000 for	6,567 50

There remains of the extra fund in the hands of Riggs & Co., $600, which, together with the $5,000 drawn from this fund in 1855 to meet payments on the building, and which may be repaid from the balance now in the treasury, will make the $125,000 intended to be invested.

The interest for six months received at the beginning of this year on these State stocks, was..	$3,690 00
The interest received from Messrs. Corcoran & Riggs on the extra fund previous to the investment was	2,533 33
Total interest on the extra fund, during 1856	$6,223 33

The stock now owned by the Institution will yield, during the present year, (1857,) an interest of $7,380.

All of which is respectfully submitted,

JOSEPH HENRY,
Secretary.

JANUARY 21, 1857.

On motion of Dr. Magruder, the report was accepted and adopted.

The statement of the treasurer for 1856 was presented and referred to the Executive Committee.

Hon. Mr. English presented the report of the Building Committee, which was accepted.

On motion of Dr. Magruder, the Secretary was authorized to have the cisterns referred to in the report of the Building Committee securely arched over with brick, and one of them to be properly arranged for an ice-house.

The Board then adjourned to meet on Monday morning, at 10 o'clock a. m.

MONDAY, JANUARY 26, 1857.

A meeting of the Board of Regents was held this day at 10 o'clock a. m.

Present: Hon. James A. Pearce, Hon. James M. Mason, Hon. S. A. Douglas, Hon. Wm. H. English, Hon. Benjamin Stanton, Professor C. C. Felton, and the Secretary.

The minutes of the last meeting were read and approved.

On motion of Mr. Mason, it was

Resolved, That the funds of the Institution deposited with Messrs. Corcoran & Riggs, for the current expenses of the Institution, be placed in the hands of Messrs. Riggs & Co., successors to Messrs. Corcoran & Riggs.

Mr. Pearce presented the report of the Executive Committee, showing the receipts and expenditures for the year 1856, and the estimates of appropriations for the year 1857.

The Secretary then presented the annual report of the operations of the Institution during the year 1856, which was read in part.

The Board then adjourned to meet on Wednesday, January 28th, at 6½ o'clock p. m.

WEDNESDAY, JANUARY 28, 1857.

A meeting of the Board of Regents was held this evening, at 6½ o'clock p. m.

Present: Hon J. A. Pearce, Hon. J. M. Mason, Hon. B. Stanton, Hon. H. Warner, Professor C. C. Felton, Professor A. D. Bache, Hon. George E. Badger, and the Secretary.

The minutes of the last meeting were read and approved.

The Secretary concluded the reading of his report.

On motion of Mr. Mason, the report of the Secretary was accepted.

The report of the Executive Committee was then taken up and adopted.

The Secretary presented various communications, &c., to the Board.

Adjourned to meet at the call of the Secretary.

GENERAL APPENDIX

TO THE

REPORT FOR 1856.

The object of this Appendix is to illustrate the operations of the Institution by the reports of lectures and extracts from correspondence, as well as to furnish information of a character suited especially to the meteorological observers and other persons interested in the promotion of knowledge.

SUBSTANCE OF A LECTURE DELIVERED AT THE SMITHSONIAN INSTITUTION ON A COLLECTION OF THE CHARTS AND MAPS OF AMERICA.

BY J. G. KOHL.

The fact that individuals often neglect one part of their education whilst they cultivate another excites in us no particular attention, because it is so very common. But that the colossal being which, with its innumerable heads, and eyes, and hands, seems to approach omniscience, and which we call *human society*, should commit a similar oversight with regard to the objects of intellectual culture, seems truly extraordinary; especially must it excite surprise that, at a time when the whole gigantic tree of science is full of active life and all its branches bear flowers or fruits, there should be any single off-shoot which, amid the general expansion, is left untended, and remains consequently leafless and blossomless.

It is strange, I say—it seems perhaps incredible, but still it is an undoubted fact—that there is in the life of the human race, and of society, taking it as a whole, always much of the blindness and one-sidedness of an individual. Like an individual, it has its pre-occupations and predilections; like an individual, an entire age is fettered by a peculiar custom or fashion; like an individual, it is forgetful; and like an individual, it suddenly calls to mind something which it had not thought of for a thousand years. The progress of the human race in science and civilization is sometimes by fits and starts, instead of advancing, as would be worthy of such a dignified body, with a slow, even, and majestic movement, like the rising of the sun.

At one period poetry and the arts flourish, and predominate over science. So, too, among the different arts and sciences each one has its epoch. They never culminate at one and the same period. There is always one that enjoys especial favor, while others are neglected.

It cannot be denied that there has from the beginning been something that was *called* geography; but it has been a plant of very tardy growth. So far as it was not a part of astronomy it was at best always considered as a handmaid to other sciences, and had never that noble independence of which it is susceptible. Even yet, geography is far from its culminating point. But we may predict for it better days. In our time, at least, some distinguished men have better defined its formerly vague limits, have organized and disciplined it, have shown what it is capable of doing, and have made us suspect that the thorough knowledge of our globe, which is the theatre of all human performance, must be the basis of historical as well as moral science; that geography, rightly understood, is not to be considered merely as the humble assistant and follower of the sciences, but rather as the guide or governor of them all.

If in our busy time, so full of activity in all directions, we can point out anything as decidedly predominating, we may say that political and natural history are the sciences which occupy us more than any other. The taste for these two branches of knowledge, which are the twin sisters of geography, is now widely and justly prevalent. They have been treated of late with more talent, circumspection, and exactness than ever; and because, to become complete and exact, they need the aid of geography more than of any other discipline, the revival and advancement of geography will be a very natural consequence of the prevailing tendency.

Naturalists have of late become more aware of the importance of geographical considerations in connexion with their studies than they ever were before. Plants and animals have been considered in relation to the soil and climate in which they were produced; and geographers have defined more distinctly the different regions to which every natural production belongs.

The intimate relations of geography to history have also been made apparent. In former times historians related the deeds of nations and individuals as quite independent of the country in which they were transacted. Scarcely a historian would give even a brief description of the country by way of introduction, and it was only on arriving at a battle-field that they bestowed a little attention on the locality and its geographical features. But in the writings even of the best historian there was no indication to be found that he was aware how the configuration, climate, and productions of the country in question influence the current of events, and, indeed, the whole character of the national history. This has now been changed, and the whole manner in which history is at present treated has become more geographical, or, I may say, cosmical. Modern historians show us more clearly how each nation forms a part of the universal life of the world. And from this necessary alliance between geography and history quite new branches of science have sprung up, of which formerly there were no examples; above all, that of ethnography, or the history of the distribution of races over the surface of our globe.

If geography itself was neglected until our days, the *history of geography* must, of course, have been utterly unknown. Geography has too often been treated as if it were a science of yesterday, which had no past. For this geographers themselves are to blame; for they, in describing the actual state of countries, have just as seldom entered into their *history* as historians have entered into their *geography*.

Yet no one can justly appreciate the value of existing information who does not know by what exertions it has been acquired. No man can rightly estimate any truth who is not aware of the previous errors through which the way to it led. A geographer ignorant of the history of his science is like the traveller of an Oriental tale, who finds himself transferred by enchantment into the heart of a strange country, without knowing by what means he arrived there.

If, as I have said, the history of geography has been utterly neglected, then I must add, that that most essential part of it, *the history of geographical maps*, has scarcely ever been thought of. For some time, it is true, every new map of the world or of some portion

of it made noise enough, and was highly valued as something precious, but only for a short time. We hear of maps which kings hung up in their cabinets and palaces, and of others which were discussed in the academies of the world, and sent from one city to another for the inspection of the learned, but only so long as they were *new*. When another new map appeared the old one disappeared from kingly palaces, and from the academies, and was laid aside to be forgotten. Or no—not laid aside; for if this had been done, if the old maps had been carefully preserved in archives and libraries, that would have been all we wanted. But these old and precious documents were allowed to perish; they were either never more heard of, or if recollected and spoken of still, it was only with contempt and to upbraid them for their "ridiculous" blunders.

They were never raised to the dignity of historical documents. The most inquisitive minds of the past century neglected them. Even the most intelligent French geographers, such as Delille and D'Anville, who died only in the time of our grandfathers, did nothing for the recovery and preservation of old maps. In fact, this branch of geographical research remained a perfect blank until our days, when other views have begun to prevail, and when some enlightened men have undertaken to glean and collect the few scattered relics which may yet be found. This change has been wrought in consequence of a generally awakened interest in historical antiquities.

There has arisen in our century a most active spirit for collecting and preserving all sorts of historical documents, which have been carefully commented upon and reprinted. In all the countries of the civilized world collections of this kind have been formed. Everywhere the rusty doors of the archives have been opened to the public at large, and have surrendered more and more of their treasures, which formerly by a narrow-minded policy were secreted from the eyes of the world. Such an enormous mass of new and critically arranged materials has thus been brought to light, that the history of every country has gained quite a new and broad foundation, and future historians will have much to do to digest and compile all this new matter. In the short space of half a century our contemporaries have discovered and deciphered more Greek, Roman, Runic, Egyptian, Babylonian, and Indian inscriptions, than were discovered in all the former centuries taken together. They have been collected partly in the originals, partly in accurate copies and fac-similes, obtained by the most ingenious processes of art, and have been deposited in accessible collections.

This praiseworthy antiquarian enthusiasm, which seems to have seized all the world in our time, has also at last influenced geographers to look around them for monuments on their own field of research, and to cast into the common treasury of knowledge the little still remaining within their reach from the carelessness of former times. As early as the beginning of this century, the late excellent and lamented geographer, Baron Walckenaer, brought together in his own house in Paris a geographical collection, containing many beautiful and most interesting old pictures of the world, and other chartographical documents. He was perhaps the first who, in his

own country, by his numerous writings drew general attention to this subject, and he has written upon it with equal taste and erudition.

In the same city a most interesting collection of ancient maps has been organized and brought into chronological and geographical order, and put up as a separate branch of the Imperial Library, especially through the efforts of that enlightened and indefatigable French geographer, the celebrated M. Jomard. He has added quite a new branch to that magnificent establishment, in the former catalogues of which we find the maps and globes scarcely mentioned as an essential element of the collection. They were mixed up with the books or the engravings; or they were considered, at the most, as a sort of curiosities, to adorn the walls of the rooms, as is still the case in the greater part of our old libraries. A good degree of order and light has also been introduced into the chaos of old surveys, maps, charts, and sketches—until lately in a most deplorable state of disorder and neglect—in the archives of the Dépôt de la Marine, and in those of the Dépôt de la Guerre in Paris. The same has been done in other collections, in which ancient maps, more by chance than by design, were preserved.

In England, a vast collection of old maps, for the greater part in manuscript, has lately been brought together by the efforts of different distinguished gentlemen, and has been added as an essential department to the British Museum. The learned Sir Frederick Madden has published a complete catalogue of these maps, which fills two or three volumes. And as in the British Museum, so, too, in many other public and private collections of Europe, more care is now taken than formerly in saving and collecting old atlasses, globes, charts, and navigator's guides, which are beginning more and more to be considered, not as mere curiosities, but as most valuable acquisitions.

The earliest historians of geography contented themselves with sometimes adorning their works with maps composed by themselves, to represent the views of the ancients. But such factitious representations are no longer found satisfactory; so that, at length, some historians have begun to copy and publish the old maps with all their peculiarities, precisely as the ancient cosmographers and discoverers drew them with their own hands.

One of the first who attempted this was the celebrated Polish savant, Professor Lelewel, who copied and engraved with his own hand a great number of valuable old maps, and published them with a copious and learned commentary.

The celebrated and most excellent Portuguese scholar, the Vicomte de Santarem, next produced a collection of most brilliant fac-similes of ancient maps, especially of those connected with the history of Africa, which he published and annotated, and which he further illustrated by a series of learned and valuable disquisitions on the history of cosmography and chartography.

With the same object, and in the same manner, the French geographer M. Jomard, already mentioned as the creating and organizing spirit of the depot of maps and charts in Paris, has been preparing, during a series of years, and has now begun to publish, the

invaluable chartographical documents, which he has collected. He presents at his own expense the benefit of his labors to the world, under the title of *Monuments géographiques du Moyen Age* (Geographical Monuments of the Middle Ages).

In Germany, likewise, some of the most eminent scholars have given their attention to this most attractive branch of study. Indeed, there are some indications that in that country the history of maps was thought of earlier than in any other. We have there as early as the beginning of the last century some essays or works on this subject. They are very imperfect, no doubt, and they were not followed for a long while by any thing more satisfactory. They appear (like so many other inventions which *germinate* in Germany without being perfected) to have slept for a century.

At the end of the 18th century, however, two Germans brought together by their private exertions, and arranged in geographical and chronological order, a most admirable collection of maps, relating particularly to America, and which is now in this country. I allude to the collection begun by Dr. Brandes, of Hanover, and continued and augmented by that distinguished geographer Mr. Ebeling, of Hamburg, afterwards purchased by a patriotic American, and now deposited in the library of Harvard University.

Since then, various old maps which were preserved in Germany have been copied, commented on, and published. An active geographer, Dr. Güssefeldt, has edited the celebrated map of the world, made by the Spaniard Ribero, geographer to the Emperor Charles V. The illustrious Humboldt has brought to light and made accessible to the public different interesting maps; for instance, that excellent picture of the world made by Juan de la Cosa, one of the companions of Columbus. His critical notes and comments on this map, to which he often alludes, are of course of the greatest value.

Moreover, the famous old globe of Nuremberg, composed in the very year of the discovery of America by Martin Behaim, who was in the service of King Emanuel, of Portugal, has at last been given to the scientific world in a most accurate and beautiful copy by Professor Ghillany of that city.

But I allude to some of these valuable publications only as instances, for it would occupy me too long to attempt to give a complete review of them. It may suffice to say, that such publications have become comparatively numerous in Germany, as well as in Italy, in England, and in other countries. It is now quite a common thing to edit old globes and maps, and to write dissertations on them. And it has almost become the fashion to adorn a geographical treatise or the republication of an old work of travels with a sketch of an old map, which some 30 or 40 years ago would not have been considered an ornament at all. The Spanish historian of the discovery of America, Navarrete, has inserted some most interesting old maps in his great documentary work. The academy of Madrid has introduced others into their splendid edition of the historian Oviedo. Nay, scarcely any place has of late published a catalogue of its town library without taking advantage of the occasion to add a copy of one of its old chartographical treasures. We find specimens in the catalogue

of the library of the city of Leipzig, in that of the famous library of Earl Spencer, in the republication of Hakluyt's Divers Voyages by the Hakluyt Society in London, in the Bibliotheca Americana of Mr. Henry Stevens in London, in the publications of the Paris and London Geographical Societies, and elsewhere.

It is a fact still more praiseworthy, that scholars on this side of the Atlantic have not been backward in doing their share both in general antiquarian and historical research, and in the special department of study under consideration. The wonder is not so great, that old Europe, where every stone speaks of the past, and where every village has its legend reaching back to the time of Cæsar, should at last have become thoroughly antiquarian, and been seized with a generally diffused passion for history. But we may well be astonished that a country like this, where even the great metropolitan cities are but as of yesterday, should already have entered with so much zeal and activity into this antiquarian and historical movement.

Historical, antiquarian, and ethnological societies have been established in almost every State and city, and even in that distant settlement at the sources of the Mississippi, which is not yet a State. Nearly all these societies have published series of interesting historical collections; while many private individuals, the Hazards, the Forces, the O'Callaghans, the Brodheads, and others, have collected the most valuable documents, relating to the general history of America, or to that of particular countries and States. The different State governments have also taken a very active part in this movement. They have appropriated the necessary funds for collecting, sifting and printing the public and legislative transactions of the States.

Amid all this multifarious historical and antiquarian activity, some geographical societies, likewise, (though not very numerous as yet,) have been founded, and they have begun to collect old documents pertaining to that particular branch of antiquarian research of which I have been treating. And though nothing great or general has yet been undertaken in this respect, still we may hail as an auspicious omen for geographical science in America the fact, that already several enlightened individuals have gone to Europe, have discovered there old and interesting pictures of this part of the world, or of divisions of it, and have brought home copies of them, to be deposited in the State archives of Albany, Boston, and other places. And thus, here, as in Europe, old maps have become the object of special discussions, and different historical works have been adorned with copies of some ancient survey of the countries of which they treat.

The work has been fairly entered upon, and nothing seems now to be necessary but to unite these disconnected efforts into a general system by placing a concentrating institution at their head.

II.—CAUSES OF THE LOSS OF FORMER MAPS.

In attempting to account for the disappearance of ancient maps, we may observe, in the first place, that the greater number are particularly destined for the use of the traveller, the navigator, and the soldier, who were probably the first classes of society which introduced the

use of them; and hence the names generally given to maps by the Romans of "*itineraria picta*," traveller's pictures. The Roman generals were provided with these itineraria, which accompanied them to the battle-field. They may have been often destroyed by barbarians in the conquered camp; they have shared the fate of their owner in distant lands; they have gone down with the navigator in the stormy waves. Besides, whoever has seen a maltreated sea-chart may easily guess how many such must have perished at all times under the rough hands of heedless mariners, even without a shipwreck.

Again, the nature of the materials, to which the precious lines of maps were committed, has often been the cause of their rapid destruction, as in the case of the maps which the Emperor Charles the Great and King Roger of Sicily ordered to be executed on solid silver plates. These silver maps were soon divided among a rapacious soldiery, and the laborious composition destroyed. Even the copper and brass plates upon which, as we learn, the Greeks sometimes engraved their maps, were too tempting a material for the rapacity and recklessness of conquerors. What a treasure for a Roman soldier the brass globe of Archimedes! By cutting it in two he could make at once a couple of camp-kettles; and with the copper-plate on which Eratosthenes had pictured his cosmographical speculations, he could at least mend his helmet or shield.

Indeed, it is not easy to find out a material for maps which is strong and indestructable, and, at the same time, useless enough for other purposes, to have a chance of escaping the spoiler's hand. Put your drawings on lead, the least valued of metals, and the soldiers will melt it into bullets; inscribe them on sheepskins, yet that will not save your work—parchment is useful for making cartridges as well as for binding books, and even should they escape the shears, your antiquated drawing may be washed off and the skins used for keeping a grocer's account, or some equally valuable purpose. Stones with old inscriptions upon them are just as good for building as rude rocks without them.

That I do not speak of mere possibilities, I will here mention a fact or two of the sort. A part of that famous map of the Roman empire called the Peutinger Table was discovered bound up, by the monks, as a fly-leaf in an old book in the city library of Treves. Another portion of a Roman map, representing Spain, and cut upon a stone, was discovered in the abbey of St. John, near Dijon, in France, where it had been built into the wall. Even paper, that wonderful and almost sacred material, to which Plato and Shakespeare, as well as Newton and Humboldt, have confided their ideas, is so convenient for wrapping up little articles of purchase, that hundreds of most valuable documents have gone to destruction in that way.

Many maps have been constructed only as illustrations of books, without which they were properly regarded as unintelligible. They were bound up with the book, and their fate was consequently much influenced by the manner in which this was done, owing to the varying customs and fashions of the book-binding art. In the olden time, when books were generally made in large folio, the maps received the same

shape as the book, and were preserved *with* it. But when the books came to assume, at first in some branches of literature, and then quite generally, a smaller shape—a quarto and lastly an octavo form, it became impracticable to make the maps conform to the size of the page. They could not be cut into pieces of any size, like the text of the book; because it is necessary to give the whole picture at once, in order to exhibit the mutual relation of all its parts. The maps, therefore, as formerly, were printed in large folio sheets; but to fit them for the small book, it was necessary to fold them. This folding of the maps, and the consequent necessity which the reader was under of unfolding and folding them up again each time he wished to consult them, was another cause why they were more rapidly destroyed than the books themselves. Here, I have no doubt, is the reason why, in so many cases, we possess the books, particularly those of the quarto and octavo form, without the old maps.

But all these causes of the rapid destruction of maps are only incidental. The principal cause of their disappearance lies in the general indifference to those remarkable productions which has prevailed at all times among the masses of the people. In consequence of this indifference, old maps have not only been treated with the greatest neglect, and allowed to perish by accidents, but they have even been destroyed intentionally.

To the common eye, old maps are not attractive, though useful, they scarcely embellish our dwellings, and accordingly have seldom had the advantage of glass and frame, like thousands of less valuable but more ornamental engravings. Hence it follows, that there are whole periods of the history of art, of which many paintings and engravings have been preserved to us, even all the cattle and chickens of a Paul Potter, and the rosebuds of a Heemskerk, though such things have been represented a hundred times; while the picture of the known world by the hand of Archimedes is wanting, though such a work could be produced but once.

The natural desire, moreover, of possessing the latest and best map of a country, or of the world, led to that lamentable contempt of old maps, which caused them to be discarded as no longer of immediate and practical use, no note being taken of their utility for theoretical purposes and for historical research, until quite recent times; even in many topographical and hydrographical bureaus they have been thrown aside as useless, or to make room for later productions. This was probably the case already in the times of the Greeks and Romans: so that when Agathodæmon made better maps than those of his predecessor, Aristarchus, they probably destroyed the latter; although they never would have thought of knocking to pieces the statues of a Phidias, to give place to the later and more perfect works of a Praxiteles. Hence we cannot attribute to the barbarians exclusively the loss of ancient works in this peculiar branch of art.

Another great cause of the loss which science has sustained in the article of maps, was the tendency to secrete them, which seems to have prevailed at all times and in all countries. There were always a few persons who set a high value on the newest and most correct maps, but who, at the same time, had their reasons for desiring to keep this

knowledge from others. So authentic a picture of an empire, with all its roads, its navigable streams, and approachable coasts, has seemed too dangerous a document to be exposed to the risk of falling into the hands of an enemy. The Roman emperor Augustus acted upon this policy, when he ordered the maps and other results of the extensive survey of the empire, which was completed under his reign, to be deposited in the innermost rooms of the palace, and that only such partial copies should be issued at times as the imperial councillors might find necessary for generals going to war, or useful for the schools of the provinces. Nor were his successors less jealous and circumspect. Domitian is said to have once severely punished one of his councillors for an indiscreet disclosure of something which those maps contained. The emperor condemned him to death, as a traitor ; some say that he even killed him with his own hands. Of course, when Alaric burnt the city of Rome, the entire collection of those precious documents was also destroyed. Had copies of them been deposited in different towns, some one of these, at least, might have been preserved for our use and advantage. So constantly, indeed, has this tendency to keep maps secret and scarce prevailed among statesmen and sovereigns, that even so late as thirty or forty years ago it was considered, in the greater part of Europe, a case of high treason to divulge anything of the official maps of the country which were deposited in its archives.

Maritime nations, and their sea-captains, have exhibited the same inclination to conceal their hard-earned knowledge from the eyes of strangers. The Greeks succeeded in obtaining certain Phœnician sea-charts, drawn on copper only, through the treason of the master of a vessel, whom they probably bribed ; and a patriotic Carthaginian sea-captain, who, on an expedition to a distant country, was pursued by some Roman vessels, is said to have driven his ship on the rocks, and to have drowned himself and his men, to prevent the journals and charts, and thus the whole secret of a profitable branch of Carthaginian trade, from falling into the enemy's hands.

The kings of Spain, from the very commencement of the discovery of America, observed great caution and reserve, and gave strict orders about the safe keeping of the maps which their captains and conquerors brought home from the New World. All the originals of these maps were deposited in the archives of Seville, and copies of them were issued only to such Spanish sea-captains and generals as could be trusted. No map of Columbus, none of Cortes, of Magellan, or any of the other innumerable explorers, was allowed to be engraved and published ; and the consequence of this system has been, that nearly all those interesting documents are lost to us for ever.

All the first maps of the New World were engraved and published in other countries, in Italy, in France, and in Germany, in which last country even the name *America* originated. They were made after a few documents and original drawings, which occasionally escaped the vigilance of the Spaniards. They were, of course, very rude sketches, and far behind what the Spaniards themselves possessed. An Englishman, the well known Robert Thorne, who was settled in Seville, was therefore very anxious that nothing should be said about it when he sent from Spain a report and a map of the West

Indies to one of his countrymen, Doctor Ley, ambassador of King Henry VIII. to the Emperor Charles. "Also, this carde," he says, "is not to be shewed or communicated there. For though there is nothing in it prejudicial to the Emperor, yet it may be a cause of pain to the maker, as well for that none may make here these cards but certain appointed and allowed for masters, as for that peradventure it would not sound well, that a stranger should discover their secretes." "And I beseech your lordship let it bee put to silence."

Whole editions of books, and probably maps also, which seemed to reveal too much of the Spanish possessions, have been bought up and destroyed by order of the court of Spain, and their authors imprisoned, of which instances are not wanting even in later times. A true Spanish map of America, or parts of it, was, therefore, considered by the English and French captains as a real treasure. When they captured a Spanish vessel, they searched her as well for the maps as for the piasters. Some of these Spanish maps captured by the English have become quite famous; those, for instance, of the coasts of Peru and Chile, which the English freebooter Rogers captured in the South sea, and which were immediately engraved and published in England, by the well-known map maker, Senex. Such instances of the casual preservation or recovery of Spanish maps show us how many valuable documents for history and geography we have lost by that system of secrecy.

But, when interest demanded it, other nations acted no better. Thus, it is recorded of the famous English navigator, Frobisher, that he kept secret the journal of his track, and showed to nobody the maps which he made of his strait and his new discovered country in the north. The consequence was, that for a long time geographers were at a loss to say under what latitude and longitude his discoveries were to be placed.

Even in our "enlightened" days, proofs are not wanting that we are not much less inclined to hide geographical knowledge, when interest prompts us to do so. One of the most distinguished geographers of our time, who wanted to complete the charts of the Atlantic ocean, applied for information respecting a certain route from New York to Brazil, to a gentleman who had formerly been a very extensive trader to those regions. "As my firm no longer exists," was the reply, "I can speak freely to you about the advantages of this route. Some years ago I could not have done it. For the thorough knowledge of it was a secret which enabled our sea-captains to regularly make a passage some days shorter than that made by others; and upon this secret our profits, in a great measure, depended."

Suppose that an American captain had discovered, somewhere in the South sea, a valuable guano island, and that he had taken its latitude and longitude, and made a complete survey of it, is it likely that he would hasten much to have this map engraved and published for the benefit of science and for general use? We think not. And thus, at this very moment, we may be surrounded by many mysteries, by many secreted maps, without being aware of it; and hence much information may be, even yet, withheld from geography by the iron grasp of interest.

III.—GENERAL INTEREST OF A CHARTOGRAPHICAL COLLECTION.

As the plant, springing from the shapeless seed, is gradually developed into an object of symmetry and life, as the sculptured form emerges from the rude block by reiterated blows of the mallet and strokes of the chisel, so America, contemplated in its successive delineations upon the maps of different periods, exhibits the growth of that gigantic work with the gradual and laborious completion of which astronomers and cosmographers have been occupied for centuries. Only, here each step has occupied a series of years: every stroke of the mallet is an adventurous voyage of a great explorer, every rude chip that falls from the block is a large (even if imaginary) country, every incision is a gulf or a river-mouth, and every touch of the smoothing file is a complicated calculation, the result of the final solution of a scientific problem, with which the minds of philosophers had until then been occupied in vain.

In looking at the earliest maps of the world, which were composed before Columbus's time, we find, midway between Western Europe and Eastern Asia, in the centre of *the Sea of Darkness*, (as the Atlantic ocean was then called,) that fabulous old land, adorned with many attractive traditions, and called by such names as the "Island of Antilia," the "Island of the Seven Cities," the "Island of the Holy Bishop Brandon." Never stationary, however, sometimes it moves more to the north, at others more to the south. On some maps it approaches nearer to the Old World, on others it withdraws further into the hidden recesses of the dark ocean. The artists and painters who made those early maps often represent this island as larger than our present Cuba. They give it an elegant form, adorn it with purple colors, or frame it in a gilded line. Sometimes all the seven cities, with their towers and cupolas, are represented upon it. And in this attractive shape it seems to invite the tardy navigator to venture upon the unexplored ocean. It floats on the waters like that little patch of sand and mud which *Menaboshu* cast upon the surface of the flood after the deluge, and from which the whole continent of America developed itself, with all its branches, its peninsulas, its islands, and its mainlands. Antilia is for the New World what the sacred lotus-flower is for the Old, which, according to Hindu tradition, grew and unfolded itself into the great islands of Asia, and bears on its branches and leaves the whole structure of that continent.

At last, with the return of Columbus, there arrived in Europe the first good news of the new-found shores, and with it came a map or sketch of that part of them which was first reached by the Spaniards. The king of Spain ordered this map to be reduced to a very small size, and to be inserted into the armorial bearings of the great discoverer. The original is unhappily lost to us; but we may rejoice that we possess at least that little reduced copy in the great admiral's escutcheon, on which it is represented, by a few lines, as a deep and spacious bay, embosoming a group of islands. When, soon after Columbus, navigators had ventured to make further excursions to the right and to the left of the Antilles, and had discovered some parts of both divisions of the continent, they were at a loss how to place and

how to represent them. Some thought that they must be two broad peninsulas shooting out far towards the east from the body of the Asiatic hemisphere. But the greater part, who with justice supposed, or who soon learned, that the eastern shore of Asia must still be far distant, imagined them to be two isolated pieces of land in the midst of the ocean. And they represented them, accordingly, as two great roughly shaped islands, more or less advancing from the Antillian centre towards the south and the north.

When the Balbaos and Corteses had reached the long isthmus countries of Mexico and Central America, those two islands at length coalesced, and we see them on the subsequent maps linked to each other by a natural bridge of mountains and continental shores.

Now, the huge bulk of the American block began to show something of its *true* proportions. At least, this was the case on its eastern side, which lay towards Europe, and with which the first European navigators soon became tolerably well acquainted, whilst the western side still remained untouched and hidden in darkness. On the maps of this period, America looks like one of the gigantic statues of gods or kings which we see carved in high relief in the rock-temples of Hindostan and Egypt. Their front parts, turned towards us, are tolerably well drawn and sculptured, but their backs still adhere to and form a portion of the shapeless mountain side.

After Magellan had pierced through his strait into the open water to the west, when Pizarro had worked his laborious way down the coast of Peru, and when Cortes in the latter part of his career, in search of something like Japan or China, had navigated to the northwest and explored the shores of California, then, likewise, this western side was cut loose from the mass of the unknown, and began to assume at least the principal features of its true configuration.

But even these principal features were as yet only rudely given. A mariner who would sail by those sketches must be on his guard, and be prepared to touch at the port of his destination some degrees earlier or later than his charts would lead him to expect. On them are projections and excrescences which ought not to be there; inlets and bays appear where in reality everything is filled up with volcanic matter and diluvial deposits; and large islands, as for instance. Newfoundland, are still attached to the whole continent. The extreme north and south of the continent, where no one has yet ventured to sail, are still for a long while left to fancy and speculation.

In the north, these speculations assumed particularly numerous and varied forms. On some of the maps of the middle of the 16th century we see a long continental bridge or archway built from Scandinavia to Greenland, and this part of America thus attached to Europe. On others this same Greenland, and with it the entire arctic regions of America as far down as Newfoundland and Mexico, are annexed to Asia, and are represented as a prolongation of Northern China or Tartary. Very slowly and reluctantly the constructors of these maps surrendered their preconceived notion, that *Mexico* was the next neighbor of Japan, Shanghai, and Canton. However, every 20 or 30 years, Japan retreated a little further towards the west. Every half century the broad gulf in the Northern Pacific widened a little

more. Whether and how America was connected with Asia and Tartary, continued to be long disputed, until at last, scarcely one hundred years ago, the Russians pointed out the strait that bears the name of one of their renowned explorers, and the united efforts of Spanish, English, and Russian navigators brought everything into its right place.

Scarcely less slow was the progress of light in the southern region. For more than a century after Columbus, the southern island, called "the Land of Fire," was pictured as a part of a great imaginary southern continent, which covered and barricaded the ocean from Magellan's Strait to the Antarctic pole. This southern continent is represented on our ancient maps as nearly of the size of Asia. New Holland, New Zealand, and other islands are all made a part of it. It receives at different times very different dimensions, and alternately contracts and expands, like the cloud which Hamlet showed to Polonius, and which, according to the disposition of the beholder, took the shape of a camel, of an elephant, or of a bird. Some said this continent was peopled by above 25 millions of souls, and the map designers embellished it with cities and castles, with forests and animals of different kinds. Into this cloud dived at last, in the beginning and middle of the 17th century, the Dutch and British navigators, and made it disappear from the geographical horizon by rounding the stormy cape.

In like manner, Newfoundland and other islands were successively detached from the continent. The Gulf of St. Lawrence and other large Mediterranean bays were roughly traced out. Still the image of America was as yet nothing but an *outline.* The whole vast interior remained a blank, or at least was more filled with products of the imagination than with portraits after nature. The movements of navigators were by their nature quicker than those of land travellers. And not only so, but the latter continued for a long time to be less scientific, and were less provided with appliances and instruments for astronomical and other observations.

Consequently, our old *charts* of America are generally better than our *maps,* on which the rivers with their innumerable branches are endlessly perplexed; while mountains and plains show such anomalous and varying configurations, that the whole continent at first sight appears like a huge kaleidoscope, the materials contained in which were constantly subjected to new and fantastic transformations.

Still, there is a method even in their madness! For, if we look a little closer at these fanciful delineations, we may sometimes discover that, erroneous though they may be, still they are not downright falsehoods. There are few which are not founded upon *something,* upon an old tradition, upon a favorite notion of the time, upon a geographical hypothesis, or at the least upon reports of the wild Indians, which, it is true, were sometimes misunderstood. We could exhibit, for instance, maps of this time, on which the great river of St. Lawrence is represented as much larger than it really is—as occupying the whole locality of the upper Mississippi and Missouri, and running through the entire broad continent of America. Yet looking with due discrimination at the circumstances, we perceive that, according to the state of information at the time, the old map

maker could scarcely have given us any other St. Lawrence than he has done.

All the geographers of the 17th, and of the beginning of the 18th century, believed with an extraordinary tenacity in the existence of a great lake in the interior of South America, between the Orinoco and the Amazon rivers. You see this lake represented on the maps nearly as large as the Caspian sea, of a quadrangular form, surrounded by most picturesque mountain scenery, upon the neat drawing of which much pains have been expended. On the shores of that lake, called the great *golden lake of Parime*, was painted at its western corner the large city of Manoa, with an abundance of palaces, towers, and cupolas; and to this was sometimes added the portrait of the sovereign of this city and region, the Emperor *Eldorado*, who was said to be a lineal descendant of the Incas of Peru, and the possessor of their accumulated treasures.

This tradition of Eldorado, with his city and beautiful lake, was a natural product of different circumstances. It partly grew out of the golden dreams in which the European nations indulged after the discovery of Mexico and Cusco. Partly it was founded on good historical grounds, on certain events in Peru, where some cousins of the Incas retired with treasures to the interior. And partly, it must be owned, it was the result of pure deception. The question then naturally arises: Are those maps worthy to be preserved, and to be noticed by the historian of geography and discovery? Have they had any influence upon the present state of our knowledge? And can those old delineations of the lake of Manoa help us to understand better our modern geography of that region? I do not hesitate to answer all those questions in the affirmative.

Those very chartographical fictions were the cause of innumerable useful expeditions. The whole history of the settlement and exploration of Dutch, English, and French Guiana is essentially connected with the fiction of the city and lake of Manoa, without which probably those extensive American colonies would never have been called into existence. The whole exploration of that region is a hunt after the objects named; and we could not understand a single expedition made in this direction, without being fully informed respecting the position properties, and shape attributed to that lake, which has only of late been dissolved and drained into such narrow river courses as now take its place.

When at last the Jesuits, those excellent astronomers and mathematicians, took out of the hands of the Pizarros and the De Sotos the continuation of the work of Columbus; when they brought the astrolabe and compass from the shores into the interior; when father Fritz, and after him La Condamine, had worked their way down the whole course of the river Amazon; when the members of the same order had explored all the branches of the great La Plata and Orinoco in the southern, and had reached the westernmost end of the St. Lawrence in the northern continent, the great secret of the New World was at length wrested from the hand of Nature, and its main features stood clearly revealed. As with the whole continent, and its great lakes, rivers, and mountain chains, so also with every smaller part

and sub-division of them, each had to go through certain traditional and poetical periods, till it gained that certainty in its outlines which it at present exhibits.

Every blue summit of a mountain descried by your western settlers and pioneers from a distance, every large or small branch of a new river, every glittering surface of a lake never seen before, was talked of by them around their camp-fires, and gave occasion to all manner of hypotheses and speculations about the end of the lake, about the direction and source of the river, and about what those mountains might be, what they might contain, and how they might be connected with the rest. And what those bold pioneers surmised, and what they heard from the Indians in the west, all found an echo in the cabinets of the geographers of the east, and you see it conscientiously transferred to their maps, which are changed and corrected a hundred times, till at length a Champlain, a Boone, or a Clarke fits out his expedition and sets the matter at rest.

To follow out such laborious undertakings, and to trace the zigzag lines of their progress through the course of whole centuries, may to some appear a very tedious work. I regard it, on the contrary, as a branch of investigation both novel and exciting. It is a department of historical inquiry which is unique in its kind, because it treats of human efforts and achievements which when once brought to a satisfactory termination are incapable of renewal. Asia, in the course of ages, may yet be conquered by more than one Alexander or Genghis Khan. But a Columbus will never appear again, because he performed a work which, from its nature, can never be repeated. The islands, and mountains, and rivers, of our globe are numbered; and the time must arrive when the race of discoverers shall become extinct. But the glory of the Corteses, the Drakes, the Cooks, will then shine brighter than ever. These were the men who struck the great blows in carving out the right figure of our globe, and in fundamentally changing the aspect of all human affairs. They wrote their names on the rocks and shores which they discovered, and there they will stand so long as the pillars of Hercules and the limits of the ocean, and of the dry land shall last. Their history, as I have said, is *unique*, and therefore ought to be written and delivered to posterity with especial care and accurateness. If we, who are comparatively still near to these remarkable events, omit to do this, if we neglect the valuable documents which are still at our command and allow them to perish, posterity will justly reproach us with having deprived humanity of a part of its most interesting records.

IV.—USE OF FORMER MAPS FOR COMPLETING AND TESTING THE ACCURACY OF THE NEW ONES.

The field of geographical research through all the vast regions of a great continent like America is immense. And although scientific observers are now more numerous than ever, it has been perfectly impossible for them to bring up the observations of every point, harbor, cape, and inlet, of every source, turn, angle, and mouth of a river to the point of accuracy which science now demands.

In fact, I believe the number of places of which the position, nature,

and configuration have been determined, with that nicety and perfection which astronomical instruments and processes render possible at the present day, is still comparatively small. A German geographer, Mr. Doppelmayer, believed, after conscientious research, that in the year 1740 there were, on the whole globe, only 116 places the position of which had been satisfactorily ascertained. In the year 1817 another German geographer, Mr. O'Etzel, estimated the number of places on the globe the astronomical position of which had been thus satisfactorily determined, at about 6,000. Of these 6,000 places probably two-thirds were in Europe, leaving only 2,000 for the rest of the world. Although since that time the sum of observed places may have been doubled or trebled, still it must be very small in comparison with the enormous number of points which ought to be known. From the small number of perfectly well ascertained positions we find a long series of points, the positions of which is pretty well known, from computation, from terrestrial measurement, or from astronomical observations of approximate accuracy, down to those whose latitude and longitude have not been fixed at all.

The same is the case with respect to all observations other than those of position; for instance, with respect to the configuration of the outlines of a bay or an island, or in regard to the soundings of a harbor or bank, or to the height of hills, capes, and mountains. The amount of science and activity at the present day is great, still it is not omnipresent, and through the whole course of the history of geography there has never been a moment in which it could be said that for every place all had been done that the state of knowledge at the time permitted. There are many harbors in which no regular soundings with improved instruments have been made for half a century or more. There are mountains the height of which, as laid down in our present books and maps, is the result of observations made with very antiquated instruments and processes. There are numerous lakes or remote river sources where no scientific exploring expedition has been since the time of La Condamine.

"I sometimes find, to my surprise, in a 'very old book,'" says the intelligent Bishop Kennet in the introduction to his valuable American Bibliography, "one cape or one sand-bank much more accurately described than it is done in one of the newest coast pilots." The same thing may be said of old maps. A chart of 1800, though upon the whole antiquated, may often contain of some part of the coast, which then was particularly explored, a much better representation than is found in those of a later date.

Again, the different classes of observations laid down on one and the same map are of very different value. On one survey the soundings may be quite accurate, while, perhaps, the astronomical position and the configuration of the coast is better given on a map of another date. Some explorers have had particular facilities, inclination, or talent for one or other of the numberless branches of geographical observation, and one has thought of that which was overlooked by another. The results of all these observations, from early times to the present day, have been laid down partly in books and partly on innumerable maps; and nothing but a complete series of these can

enable us to know what has been done and what remains to be accomplished in this vast field of research. Hence it is evident that very seldom, if ever, can we determine when an old map is really obsolete and of no further use at all.

The work of surveying, exploring, and map-making, is, like every other human pursuit, capable of an endless approximation towards perfection. It is constantly progressive—particularly as regards this new world, America. There is an inaccuracy of expression when we speak of the *discovery* of America by Columbus. The great work of the discovery of America was only *begun* by Columbus; it has been going on for the last three centuries, and cannot yet be said to be completed. And, therefore, here especially an institution is wanted the business of which shall be to follow and record step by step this progress, and thus become a common fund and treasure-house of all preceding and contemporaneous discoveries.

Truth and error are handed down together, from generation to generation, through the history of mankind. It is curious, that while this is often admitted to be the fact as regards the history of other sciences, geographers until now seem to have believed that it has no application to chartography—a science which, according to them, like the phœnix, each day is consumed and each day is born again from its ashes; but, to show how false this notion is, I may cite the statements of the able author of the article on Geography in the Encyclopædia Britannica, who says that the tables and measurements of Abulfeda and of Nazir Eddin, and the maps of the interior of Asia, made under the enlightened Calif Almamoun, were, as late as the year 1817—that is to say, about 1,000 years afterwards—of use in the construction of the maps of some parts of Asia.

On the other hand, the longevity of errors in geography, and consequently in maps, may be illustrated by the following instances: It is well known that the great father of geography, Ptolemy of Alexandria, committed the extraordinary error of assigning to the Mediterranean sea a length of not less than sixty-two degrees of longitude, which was upwards of twenty degrees too much. This amazing mistake affected all our maps of the Mediterranean more or less until the beginning of the last century. Many astronomers and navigators knew, long before that time, that the Mediterranean was actually much shorter, and many map-makers ventured to cut off a few degrees, despite the statement of the great Egyptian; but so absolute was the authority which he enjoyed amongst Christians as well as Arabians, that they were extremely slow in deviating from him, and came down to the truth very unwillingly. In this instance the contest between truth and error lasted more than 1,500 years, until at length the French geographer Delille gave to the sea its true limits. But if such a thing could happen with respect to the Mediterranean, which from the beginning of commerce and civilization was the best known part of the world, is it not highly probable that we may discover similar longeval errors in such little known countries as, for instance, the interior of Patagonia or Brazil; and that, by studying and comparing the maps, we may trace these errors to their source, and so help to correct them?

Another equally remarkable though not so old an instance of the long continuance of errors on maps, is presented to us in the works of the great French geographer, Buache. He conceived the idea that the whole surface of the earth was divided into certain principal and lateral basins, each of which was surrounded by mountains, whilst its central part was occupied by a great lake or ocean, into which rivers flowed on every side. This conception was, to some extent, true; but Buache carried it to an extreme, and, his head being full of this idea, he drew on his, in other respects valuable, maps as many basins as could in any way be brought into seeming harmony with ascertained facts. A French savant says, in a work of the past year, that his system still exercises a pernicious influence on the best French map-makers, who, inheriting the theory of Buache, have continued to propagate its fanciful deductions.

The old maps, therefore, are not only precious for some hidden treasure of truth which they may contain, but just as valuable for the facility which a series of them affords for tracing traditional errors. "All maps," says a British geographer, "should be considered as unfinished works, in which there will always be something to be corrected or something to be inserted."

Buache, Forster, La Condamine, Humboldt, and other enlightened geographers, have shown how useful they considered the knowledge of the opinions of former cosmographers, by taking the trouble to compose what they called maps of errors. La Condamine composed a comparative map of the course of the Amazon river, on which he showed, with different colors, how the direction and bends and branches of this river were represented by different geographers.

Buache and Forster made maps of the northwest coast of America, on which they combined, in one picture, the outlines of that coast, as they found them represented on the authority of a number of different observers.

Humboldt composed, with great care, a map of Mexico, with the erroneous astronomical positions of many important points of that country. Others have done the same for other parts of America. But these so very useful and instructive maps of errors form a class of scientific compositions which are not yet as much in use as they deserve to be. They are probably so rare because there exist so few chronological collections of old maps. And this again proves how desirable, how necessary, such collections are. We cannot dispense with them, so long as we cannot say that every part of our maps is above all criticism, and so long as the picture of the whole continent, in all its parts, is not laid down with absolute and minute accuracy. Only when this shall be the case, will we be justified in cutting loose our connexion with the past; then only can we cast overboard the whole erroneous structure of our forefathers, or consign it at least to our collections of antiquity, as a mere matter of curiosity.

V.—MAPS AS HISTORICAL DOCUMENTS.

Historians, geographers, and travellers, have laid down on their maps many things of which they have not spoken at all in their books,

either because they inserted on the map what they had omitted in the book, or because they found it easier and shorter to speak to the eye than to the ear.

Maps, therefore, form a peculiar class of historical documents. Sometimes they confirm what we have in the books, sometimes they make our literary information more complete, and sometimes they must serve us *instead* of books. It is particularly the old maps which have this documentary character. Martin Behaim, when he composed, in the year 1492, his celebrated globe, was not content with giving merely the outlines and names of the countries and islands which he depicted, but he added to each of them quite lengthy descriptions, in which he informs us what kind of people lived in each country, what plants were raised there, and, occasionally, by whom and when it was discovered.

The same thing was done by many other map-makers, on whose delineations we find inscriptions like these: "In the year 1500, Bastidas sailed as far as this point." "Here Solis was killed." "On this island the Portuguese found signs of gold," and the like. Travellers, too, have often been in the habit of jotting down their observations and conjectures on the maps they composed in travelling.

It is not seldom the case that maps contain the only hints and data which we possess concerning an expedition or a discovery the reports of which have been lost. Historians have, in this respect, not yet derived all the advantage from them which maps are capable of affording. It has been questioned, if the first Portuguese expedition along the eastern coast of South America, could have gone as far south as they pretended to have done, that is to say, beyond the fiftieth degree of south latitude, and if the Portuguese explorers of the beginning of the sixteenth century ought to be considered as the discoverers of the Falkland islands. Different very old maps, which show a group of islands in the true latitude of the Falkland islands, can be quoted as documentary proof of the truth of that assertion. That the Spaniards knew the Sandwich islands a long time before Cook, that they had a name for them, that they probably visited them repeatedly, was proved by a map which Admiral Anson found on board a Spanish vessel, and on which those islands were laid down in their true position, and is proved likewise by still older maps, on which we find a group of islands, called Los Volcanos, laid down in the latitude and longitude of the Sandwich islands. Some other old maps, which have recently come to light, have large tracts of the Australian continent very accurately depicted, and prove to us that the Portuguese and Spaniards were acquainted with those countries a long time before the Dutch and English.

The printed books inform us imperfectly about those highly interesting expeditions which Cortes ordered to be made into the Gulf of California, and along the western shores of the Californian peninsula. A map of these regions, which was made by a contemporary of Cortes, and which, at the end of the last century, was discovered and publised in Mexico, completed our knowledge of these expeditions in a very satisfactory manner. It showed us exactly how far the captains of Cortes ascended the Rio Colorado, what names they gave to the

harbors and capes, and which was their *ne plus ultra* on the western coast.

Many assertions in history are of such a kind that we do not give to them a very high degree of credence, if we find them only reported in books. But if we see the same thing also depicted on a map, our conviction of the truth is enhanced. So, for instance, many may doubt the fact, reported in Spanish authors, that as early as the year 1519, the Mississippi was discovered by the captains of the Conquestador Garay. But when we produce to them maps of the period on which, not only the whole configuration of the northern coast of the Mexican Gulf is given according to nature, but on which also in the middle of this coast a broad river is depicted, having the true latitude of the mouth of the Mississippi, they feel much more inclined to believe the asserted discovery.

The history of the cosmographical speculations and hypotheses, which prevailed at the different periods of geographical knowledge, forms a very interesting chapter of the history of science and civilization. These speculations, it is true, were also usually treated of in books. But they are sometimes so fanciful and wild, that we can scarcely credit their having ever been seriously entertained. When, however, we behold them carefully drawn on maps, and find that those maps were reproduced a thousand times, and passed into every hand, we clearly recognise how deeply rooted those speculations or prejudices must have been in the minds of a former age. We learn, for instance, that the Dutch, when they discovered, north of Japan, the island of Yesso, imagined it to be a large country, reaching from Asia to America. At first it seems scarcely possible that such an erroneous supposition could become the conviction of the time. But the Dutch not only described this fanciful continent of Yesso in their books; they also laid it down on their maps as a bridge extending from California to Tartary, with the inscription: "This is the land over which the seven Israelitish tribes wandered from Asia to America." They delivered such maps to all their contemporary students and navigators. And these maps, therefore, prove to us, more than books, to what a degree these contemporaries must have been impressed with those speculations.

Very often the maps of a time are the only guides which enable us to guess the real design of the expeditions sent out for discovery, and to explain the movements of their commanders. In this respect, we may observe, that the published reports and books very rarely give us full information on the subject. The reports which we have, for instance, of the expeditions of Bartholomew Diaz, of Vasco de Gama, of Magellan, of Drake, of Hudson, were not written by the commanders themselves, but by some "gentleman" accompanying them, a missionary or volunteer, who only occasionally was induced to take notes of what he considered worthy of record. The papers and maps of the commanders themselves went generally another way. They were deposited in the archives of the governments, and are in innumerable instances lost to us.

From such second-hand information as we have, we therefore learn many curious things and events, which happened to be observed by

the occasional passenger, or "gentleman companion." But we very rarely find an allusion to the maps which they had on board, and after which they sailed—no description of the astronomical instruments used by the officers, no explanation of the leading ideas of the commander, and the reasons for his conduct, or of other decisive points of the sort, which a historian principally wants to know, but which were kept secret from the journalists.

The study of the maps of the time, and the comparison of them, can do much towards supplying this lacking information. If we have fixed the dates of the maps, we can prove what sort of guides those commanders were likely to have had with them. We can show what notions they must have entertained; and, in many cases, we can guess by what reasons they were influenced to act as they did.

There is only one class of expeditions respecting which we have that full and complete information which is desirable, namely, the recent ones performed by the English, French, and Americans. For them we have the parliamentary papers, in which the motives of the expedition are discussed at large. There we hear the commanders speak themselves, and give us the amplest description of their whole outfit, and instead of being forbidden they are even required to give to the public all the explanations necessary for understanding their proceedings; while on the construction and publication of the maps and charts, which are to form a summary of the entire geographical results, especial pains are bestowed.

VI.—USE OF THE OLD MAPS WITH RESPECT TO BOUNDARY QUESTIONS AND OTHER POLITICAL TRANSACTIONS.

There are no countries in the world which have been from the very beginning, and still are, so much agitated by *boundary* questions—and in which, therefore, reliable maps, as the principal means of settling these questions, are so much wanted—as the different colonies, empires, and states, of America.

Scarcely was America discovered, and scarcely had the Pope drawn his famous line between the possessions of Spain and Portugal, when there arose a boundary dispute of the widest extent between those two powers; one of which desired to include in its limits nearly the whole of Brazil, whilst the other tried to prove that its competitor ought to be almost entirely excluded from the continent.

The commissioners of Spain and Portugal discussed this question at different lengthy sessions, but without conducting it to a satisfactory solution—partly because the maps and charts which were produced on both sides did not agree, and partly because they found themselves unable to locate their boundaries on the surface of the earth.

The Hispano-Portuguese boundary question forms the most essential element of the whole history of South America. It runs through a space of 350 years. It was revived at every step which Spanish and Portuguese discovery and conquest made in opposite directions. It was, after all, only partially and roughly settled. The question descended as an heir-loom from the royal contending parties to their modern repub-

lican and imperial successors, and it remains a debatable matter to this day. The whole empire of Brazil is still surrounded by boundary disputes springing from that contest.

As among the different sovereign powers, so also among individual Spanish discoverers, questions of this sort were a fruitful source of contention. The Spanish kings, in their contracts with their so-called "*conquistadores*," used to promise them that they should become governors, commonly hereditary ones, of the new countries within the limits of their discoveries or conquests. These limits differed greatly according to the different views which the conquistadores themselves entertained of their own merits and the extent of the fields of their activity.

Hence arose the famous quarrels between Cortes, the conqueror of Mexico, and Garay, the discoverer and governor of the countries north of the Mexican Gulf. Cortes wished to carry the limits of his province as far *north*, and Garay as far *south*, as possible. Similar disputes existed for some time between Bastidas and Ojeda, and between Columbus, or his heirs, and all the other discoverers.

Pizarro, the conqueror of Peru, had a similar quarrel with his companion, Almagro, the conqueror of Chile. When the three great conquerors of Cundinamarca—Quesada, Benalcazar, and Federman—marching into the Magdalena valley from different sides, met on the high plateau of Bogotá, a question arose as to how the new country should be divided. This they finally agreed to submit to the decision of the King of Spain. During the ensuing lawsuits, maps were made and produced which showed the limits and extent of the several discoveries; and on the decisions based upon these documents rest the boundaries of provinces and empires to this very day.

When, at a later period, the French began to extend their conquests in Canada and the English their settlements on the Atlantic coast, a whole series of collisions respecting the boundaries of the different powers commenced. At first between France and England, about the limits of Canada towards the south, and of what was called Virginia towards the north. Afterwards between France and Spain, about the extent to be given to the newly created province of Louisiana. And again between England and France as well as Spain, respecting the boundaries of the countries beyond the Alleghany mountains, and likewise in Florida and in Nova Scotia.

We may say that during the whole of the seventeenth and eighteenth centuries no war was carried on in Europe which was not partly a war for the extension of colonial boundaries in the New World, and no treaty of peace was concluded which did not comprise articles on the same subject. On all these occasions American maps were of the greatest use, and were on all sides much sought after. The French and English commissioners, for instance, who discussed, in the middle of the last century, at and after the treaty of Aix-la-Chapelle, the question of the limits of Nova Scotia, collected, used, and criticised as many at least as fifty American maps of the earliest as well as the latest date.

Some of these boundary questions, in the unfinished state in which they were left, were afterwards inherited by the great North American

republic; and in the negotiations respecting its limits towards the Mississippi, towards Florida, and towards Canada, both early and recent maps were always in demand, and could sometimes only with difficulty be procured, because there existed no collection or depot for preserving and keeping them in order.

The predominance in America of boundary questions, above all others, strikes us not only in an international point of view, but also when we look into the history of each particular State and province. All the different colonies which the English planted on the eastern coast of America have had, from the beginning, like the Spanish discoverers and conquistadores, quarrels about the degrees of latitude and longitude, the rivers and the mountains, to which their territories ought to extend. Disputes of this kind have been innumerable, whilst few or no quarrels from any other cause whatever have arisen to disturb their peaceable relations. Such were the boundary questions between Massachusetts and Rhode Island, between New Hampshire and Maine, between Connecticut and the old Dutch colony on Hudson's river, between Georgia and Florida, between Carolina and Virginia, Pennsylvania and Delaware, &c. This last, the Maryland boundary question, commenced with the very foundation of that colony, and gave rise to endless treaties, lawsuits, surveys, measurements of degrees of latitude, and constructions of maps, which occupied more than a century. Nor can it yet be assumed that all the maps illustrating Mason and Dixon's line are superseded, obsolete, and of no further practical use.

The same may be said in relation to the subdivision of the great colonies and States into counties, and of the further division of these counties, which were at first very large, into smaller counties and into townships. The necessity for consulting old maps and for constructing new ones was endless.

The same peculiarly great importance which maps possess in America, with respect to defining *State* boundaries, they have also with respect to *private* landed property. In Europe the greater and smaller divisions of landed estate have been from time immemorial included in long known and settled limits, indicated by natural or artificial metes and bounds. Further, such extraordinary and wholesale grants of land have never been made in Europe as was customary in this new world, which has been parcelled out in lots, sometimes of enormous magnitude. Never was there such a lawsuit in Europe as the celebrated one of the heirs of Lord Stirling, who laid claim at once to as many millions of acres as would be equal to the surface of some European kingdoms; a suit which was at last decided with the help and by the authority of a geographical map.

As broad grants of land were once made by the English and French kings in Canada, Virginia, Louisiana, &c., as by those of Spain in Florida, Texas, and the Mississippi valley; and consequently, to this very day, lawsuits in which some large portion of a city or county is made the object of the claim are here matters of not uncommon occurrence; and in all these sorts of claims former maps are often the only authoritative documents that can be referred to for a decision.

Thus it is evident that chartography runs like a colored thread

through the weft of America history, through all the great political transactions as well as the arrangement of private affairs, wherein it becomes ramified into innumerable branches. And still this country has never yet thought even of establishing an institution to supply every branch of the government with a kind of information the want of which is so continually felt. It is to be hoped, however, that in this respect America will yet point the way to the older nations of the world.

VII.—USE OF FORMER MAPS IN DIFFERENT PRACTICAL QUESTIONS.

Although in its principal features the configuration of the surface of our globe remains unaltered, still there are continually going on, in every part of it, changes which appear insignificant in comparison with the great mass of our continents and oceans, but which are sometimes of the utmost importance for the pigmy works of man and for the enterprise and existence of nations.

Our mountains are constantly being lessened in height, our rocks crumble down from year to year, never to be built up again. Sometimes a volcano or a new island rises from the depths of that fiery abyss which is concealed under our waters and blooming lands. Our rivers are continually changing a little the direction of their courses. They abrade their banks on one side, and break through with new branches, whilst the opposite side is left dry and allowed to increase. They gradually float away old islands, or form new ones which did not exist before. The changes are particularly great at the mouths of the rivers and in their deltas near the sea-shore, where the current encounters the influence of the motions of the sea and its strong winds. There one arm of a river is choked with sand, and in time entirely disappears, whilst another gradually deepens, and from a little creek is transformed into a broad and navigable channel.

On the shores of the ocean itself the changes are upon a larger scale. The sea has swallowed whole tracts of country, and has produced new ones from its depths. In the course of centuries, banks of sand are formed, or shift their place. Many capes and peninsulas are continually melting away under the action of the waves; others grow larger under the influence of the meeting of contrary currents; whilst others, again, seem only to vary their position, and, like enormous pendulums thrown out into the waters, show a tendency to increase for a certain period on one side, and then for a like period on the other.

It is even believed that the very foundations of the gigantic crust of our globe are not quite settled yet, and that some parts of our coasts are constantly heaved up from beneath, whilst others by a slow process are sinking; whence it results that they are perpetually varying the outlines which they form with the unchanging level of the ocean.

An accurate knowledge of these changes and their tendencies is not only very interesting for the history of the past and for general science, but is also of the greatest consequence for the future and for practical purposes.

Some of the processes by which those changes are effected are rapid in their action, and can be observed and recollected by indi-

viduals or families living on the spot. Others are extremely slow, and go through so large a space of time, that the particular circumstances escape the memory of individuals and even of generations, and can only be ascertained from history and written documents. These recollections and traditions of the local population, as well as the re. cords of local history, are always valuable and may be consulted- But in most cases, especially if a particular application of the phenomena is to be made, such a precision as to the facts, and such a nicety of observation are requisite, as can only be obtained by a series of mathematically accurate pictures, that is to say maps, of the changed locality.

If our forefathers for two or three centuries past had been as correct, conscientious, and minute in the construction of special maps of all parts of a country, of its rivers, coasts, ports, banks, &c., as we now are, a complete collection of their maps would be invaluable. But even as they are, incomplete, often unreliable, and for the most part too general, they are for the history of those changes and all that depends upon them of the highest importance; because they often are the only documents which wo can consult, and from which we can form a judgment.

How desirable also in this respect a complete collection of former maps would be has been observed in this country on various occasions. Harbor commissions, coast survey officers, military engineers, architects, in constructing bridges or moles for the protection of ports, have repeatedly felt this great and essential want.

There is perhaps no other country in the world which has such changeable coasts and rivers as the United States. The whole extent of the shores of the Mexican Gulf, more than 1,500 miles in length, are low, and consist of shifting materials, partly of sand and partly of coral rocks. Changes on a great scale have occurred there every year as long as the Gulf has been known to us. A mighty circular current, accompanied by many side currents, moves in this large basin, and is constantly at work, abrading and altering after its own manner the configuration of its coasts. Heavy gales, and consequent inundations, are frequent phenomena; of some of which it is recorded that in the short space of one or two days they have torn asunder islands, filled ports, heaped up sand-banks, destroyed settlements, and thus changed at once the whole physiognomy of a long coast-tract of some hundreds of miles.

Into the Mexican Gulf empties that mighty river the Mississippi, the delta of which, one of the most interesting in the world, is a perfect labyrinth of natural changes. This delta has been explored, and somewhat more accurately studied since the time of the French discoverers, Iberville and Bienville, about a century and a half ago. These Frenchmen gave their names to branches of the Mississippi which now no longer exist. They built fortifications and beacons on the then extreme spits of land, which are now situated far in the interior. They speak in their reports of sand-banks with deep soundings upon them, which now have become inhabited islands. They would in many parts scarcely recognise the old Mississippi delta in the maps which we could now lay before them. No harbor can be

undertaken in this delta, no water-work built in one of its bayous, no channel can be cut, no sort of improvement proposed, but that at once a question arises about the former events at that place, and the men commissioned with the execution of the work must carefully study the history of the locality where the contemplated improvement is to be made.

Nearly the same is the case with the whole extent of sea-shore on the eastern side of the United States, from Cape Florida to Cape Cod, a line of more than 1,500 miles. All these shores are likewise low and sandy, and form a barrier very easily affected by the attacks of the mighty Atlantic. There is on this coast scarcely a harbor in or before which changes have not taken place at some period or other. The far stretching beaches of North Carolina, of Maryland, and New Jersey, have been broken through by the waves at different times and places; and the same waves have shut and filled up in another year the gaps they had previously made. The whole coast of New Jersey is believed to be in a state of subsidence. Entrances formerly navigable have completely disappeared; and some of these ocean doors, the history of which we are somewhat acquainted with, appear to have been alternately opened and shut again nearly every ten years. The spit of land which forms the famous cape of Sandy Hook has been in the course of 50 years four times an island, and four times again a part of the mainland.

To watch closely all these changes, and to follow them and lay them down on paper with rule and compass, would have no other than a historical interest for us, if they did not follow in their motions certain *laws*, if the currents, waves, and gales of the ocean, with their destructive results, operated accidentally like the flashes of lightning, which fall now here and now there. But from what little we know it is quite evident that such laws exist, that the Ocean in his attacks follows a certain strategic *plan*—directing his unwieldy powers for one period constantly in a certain way, and for perhaps another century in an opposite one—leaving certain points unharmed, and assailing others with uniform persistency. But if the ocean thus follows a certain plan, then it is obvious that this plan is worth studying; that we must try to avail ourselves of some such strategic art as may enable us to countervail its action, and prevent or at least avoid mischief; and that it is in many respects most essential for us to know the points which have for ever remained safe, and those which are the most exposed, and the manner in which they have been and probably will continue to be assailed. And there is no other means of acquiring this information than by constantly, from year to year, daguerreotyping the physiognomy of these coasts, and in this way detecting the laws of those unwieldy movements.

On this side of the Atlantic there are only the coasts of Maine and parts of New England which are so rocky, so elevated, so soundly built by nature, that they may almost be called unchangeable, and for which, consequently, former maps, in respect to the observation of physical changes, would be of little use. But even in the neighborhood of these coasts there lie, on the bottom of the ocean, many broad banks and shoals the soundings of which may not be always

the same, and which should therefore be watched and studied in like manner. At all events, those solid and unalterable coasts of Maine form a not very considerable part of the entire coast of this country; and I repeat it, therefore, that in the whole domain of the active commercial and navigating nations of the European stock there is no country which so much as this is in want of those documents and records of the past which we call *maps* and *charts*.

VIII.—ON THE DIFFERENT CLASSES OF MAPS.

The interesting matters which are subject to geographical distribution, and which are at the same time capable of a graphical representation on maps, are very numerous; nay, we may say they are innumerable. There is hardly any phenomenon either in the moral or in the physical world which does not undergo some change according to the position of its birthplace on the surface of the globe; and these changes and their degrees may almost always be expressed by lines, shadings, and colors. Consequently, our geographers now present us with many different classes of maps—physical, hydrographical, political, historical, moral, administrative, &c. The question, then, arises, whether we should admit into our intended collection all these classes of maps or not.

The chartographical art originated probably everywhere with travellers by land and sea and their requirements. All the maps which we see mentioned in ancient times were probably more or less of this kind; as, for instance, those which the Greeks received from the Phœnicians, and which they improved upon; so, too, the maps of the Romans, who scarcely mention any other than travellers' maps, called "*itineraria picta*," (painted itineraries,) of which a separate class was formed by the "*itineraria maritima*," (marine itineraries.)

By far the greater part of the maps painted during the middle ages belonged to this class, and more especially to the class of marine maps; because the greatest map-makers of that time, the Venetians and other Italians, were also the greatest navigators. Thus we see that the art of map-making particularly flourished among the great trading and navigating nations—the Phœnicians, Greeks, and Italians. The different classes of chartographical works for which they had names in the middle ages related all of them more or less exclusively to the hydrography of the sea. Very common, for instance, were the so-called "*portulanos*," or indicators of harbors. The "*isolarios*" (books of islands) form a very curious sort of composition, also probably designed for the special use of mariners. In these insularies the authors represented and described all the most important islands of the world, which they separated from their surrounding continents.

Next to travellers and navigators, probably the great conquerors of the world were the first promoters of the art of depicting the surface of the earth. The desire to know exactly what had been taken possession of, and to see his whole empire as it were at a glance, has been entertained by every conqueror. Sesostris, Alexander the Great, Cæsar, the Arabian caliphs, were all accompanied on their marches

by astronomers and mathematicians for that especial object. Cyrus of Persia, Augustus of Rome, and the Emperor Charlemagne, after having accomplished their military work, sat down, and surveyed and painted it. Even Joshua, as we are told in the Bible, did this with his little territory of Palestine, when he had settled there the twelve tribes.

From this class of maps, made by conquerors and distributors of land, have grown our official government surveys, which often are very valuable, beçause they are made without a too great fear of expense. They generally contain the most important information as regards the political divisions of the country, and for the adjustment of boundary questions. Sometimes, being particularly destined for government use, they have not been given to the public, or at least not to any great extent. With respect to America we have many most important publications of this character, made by the French and British governments for Canada; by the British admiralty for nearly every part of America; by the Spanish hydrographical depot in Madrid for Spanish America; and by the Land Office, Topographical Bureau, the Coast Survey Office, and other branches of the United States government, for different parts of the territory of the United States. The governments of Brazil, of New Granada, and other South American States, have likewise caused splendid publications to be made descriptive of the territories under their dominion.

The observation of the stars and the movements of the other heavenly bodies seems to have attracted the attention of all nations at a very early stage of their civilization. And at a no less early period questions arose respecting the origin, formation, extent, and configuration of the world inhabited by us—questions which are intimately connected with astronomy. The attempt to depict to the eye the result of the investigations that ensued naturally led to the construction of the first astronomical and cosmographical maps.

But astronomy, although a very ancient science, remained in an infant state for thousands of years, and the first steps in the progress of navigation and discovery were very slow. We may say that, until the time of Columbus and Gama, nations had no accurate knowledge except of their immediate neighborhoods, and their deeds were performed on a very narrow stage. Hence, for thousands of years, the art of constructing maps made very little progress. The maps which were in use in the time of Columbus are not much better than those which the Alexandrian geographer Agathodæmon had composed for the work of Ptolemy a thousand years before. They do not include a greater extent of country, they exhibit no other facts, neither do they show any great improvement as regards the position of localities upon the earth's surface. In fact, the old maps of Ptolemy's Geography were even then considered as a great authority, and were often copied exclusively.

After the discovery of America and the countries bordering on the Pacific ocean and the Indian sea, the extent of the known and habitable world was much increased and the figure of the continents and the limits of the oceans were more correctly given on the maps. But it was still very long ere the classes of interesting facts

represented on the maps were enlarged and the manner of depicting them improved.

Sometimes, it is true, an attempt was made to represent on the maps certain physical features of the earth, resulting from geographical position. Thus, for instance, we have very old maps on which the whole torrid zone is overlaid with a glowing purple color, to indicate the extreme heat of that part of the world. Here we see the first rude beginning of thermographic maps. When the great discoveries of the Portugese and Spaniards had astonished the civilized world with the sight of the strange products of barbarous regions and with the accounts of the savage customs of their inhabitants, it became the fashion among chartographers to embellish the different countries and islands on their maps with figures of grotesque apes, of enormous snakes, of birds of brilliant plumage, of the precious pepper and clove tree, and of the fightings, butcherings, and feastings of cannibals. These representations also did good service in handsomely filling up vacant spaces, and thus, in a measure, concealing the artist's ignorance of the interior of the countries delineated. As these figures were not very accurately distributed, according to latitude and longitude, we see in them our zoological and mineralogical maps only in a very embryonic condition.

It appears particularly strange that the ocean should have remained for so long a time a perfect blank on the maps. Water for the old map-makers was nothing but water, and they represented the whole aqueous surface of our globe as a perfectly unvaried desert, on which no interesting change of any kind could be observed, and which, therefore, they colored blue throughout or covered with uniform lines and stripes. It did not occur to them that the surface of the ocean offers nearly as much variety in color, depth, temperature, and fitness for locomotion as the surface of the dry land itself. And long after they had become acquainted with many of these peculiarities they did not mark them on the maps.

That the ocean, in certain parts, was covered with sea-weed was known since the first voyage of Columbus. Indeed, we find the so-called Sargasso sea alluded to in much earlier voyages of the Portuguese along the coast of Africa. And yet nobody tried to indicate this remarkable feature on the marine maps, as had been done long before with the deserts of Sahara and other variations of the surface of the dry land.

The Spaniards very well knew that some parts of the ocean are rough and boisterous nearly all the year round, while others are almost always calm. They had invented for these different states of the ocean the most expressive terms: they called a certain rough part of the ocean "*el Golfo de los Caballos*," (the Horses' gulf,) and a certain quiet one "*el Golfo de las Damas*," (the Ladies' gulf.) Yet though they painted the difference so well in words they never attempted to express it by colors.

That there were certain regular currents in the ocean was also an early discovery. The great Gulf-stream, for instance, was known as early as 1512, or since the first voyage of Ponce de Leon to Florida. This Gulf-stream is particularly well and completely described in

Ovredo and in Herrera. And still nobody tried to lay down its proper outlines on a map, which would have been the best way of improving and correcting the knowledge of this important phenomenon, so useful for navigators. We find on many maps, in the neighborhood of Florida, legends like the following: "Here the water runs continually to the north." How easy, at least so it seems to us, it would have been instead of writing this down, to paint it by a few strips of color! And yet to make this step the inventive genius of a Franklin was required; for it was he who, towards the end of the eighteenth century, was the first to depict the Gulf-stream and its limits in a tolerable manner on a map, and thus give the first impulse to the improvement of our current-maps, which now form so important a branch of the art. This general omission of the currents on the maps is all the more strange inasmuch as geographers were long ago accustomed to make an exception with regard to one particular current. The famous maelstrom, on the coast of Norway, can be seen on very old maps. We find it there regularly indicated with a long, rough, spiral line. It did not strike the artists that what they did here could, with great propriety, have been extended further.

The regular trade winds between India and Arabia, with their nature, direction, and changes, were not only known but daily taken advantage of by navigators for centuries. So, too, the trade winds of the Atlantic were described, discussed, and used, at least since the time of Columbus. Nevertheless, though these air currents flow with nearly the same regularity as rivers, no map-maker gave any visible hint respecting them to the navigators to whom he pretended to furnish useful charts, until the time of our modern Rennells. Wind-maps are also a very late invention of our century.

That the level surface of the ocean covered very different depths of water was ascertained in the earliest stages of navigation, the sounding line being an instrument the necessity of which was soon recognised. The able Spanish navigator Alaminos, for instance, not to speak of many earlier ones, had explored tolerably well not only the currents and directions of the winds in the Mexican Gulf, but also that remarkable bank which runs along the west coast of Florida, and is known under the name of "The Tortugas Soundings." And yet it was not till more than two centuries after Alaminos that the Spanish hydrographers began to depict that important feature of the Mexican Gulf by running a dotted line round its limits.

The existence of the Banks of Newfoundland was known to the very first discoverers of the eastern coast of North America. Nay, for a long time these banks were the most frequented part of the North American waters, being visited, since the year 1504, by whole fleets of French, Portuguese, Spanish, and English fishermen. To have a true conception of their configuration, extent, varying depths, currents, and other circumstances, was almost of greater importance for all the navigating nations of Europe than to know the configuration of the coasts of the great continent itself. Yet, at a time when the whole east coast of North America was already very well represented on the maps, we see the George's bank, Nantucket shoals, and the other great banks before this

coast, either not given at all, or else in a shape so little like reality that it would have been almost better to leave them out altogether.

The other qualities of the bottom of the ocean, its deep valleys and lofty mountain-ranges, were of course not noticed in an age which did not possess our deep sea-sounding instruments, and which had also no practical occasion for such explorations. This practical interest has existed only since the question has been mooted, where we can lay with safety our electric wires for the connexion of the two continents. For this purpose we now explore those hidden recesses, and we may expect that ere long our pictures of the oceans will present as great a variety of scenes as do those of the dry land itself.

Before the middle of the eighteenth century, we scarcely find any trace of a separation of political and physical maps. Although the world possessed the most interesting and learned works on the plants, the animals, the nations, &c., of all parts of the globe, still it seems not to have occurred to any one that some of those subjects could be treated in a much more successful, concise, and impressive manner in a map, until, about the year 1790, a German (Mr. Crome) made the first attempt at composing a special map of the vegetable productions of the earth. At the beginning of the nineteenth century, Lehmann invented an improved method, or rather the first good method, of representing on maps the mountains and other inequalities of the surface of the earth; and from that time date our orographical maps. At a little later period, another German, named Bernhardi, began to compose maps on which the languages spoken in different countries, with their extent and limits, were indicated by colors and lines; and here we have the origin of our ethnographic and linguistic maps, which have found so much favor with the public.

Geological maps scarcely had an existence before the year 1820. After that year, geology, though still young, rapidly became a favorite science, and many geological maps were published in quick succession. Some of the first *savants* of Germany and France, Leopold von Buch, Elie de Beaumont, and others, who saw that geology could scarcely exist without maps, themselves condescended to the task of preparing these indispensible drawings. At present there is hardly any country concerning which an attempt, at least, has not been made to give anatomical pictures of what is contained beneath its surface.

When, at last, the ice was broken, progress in this direction was rapid, and soon the German chartographer Berghaus composed his great Physical Atlas of the Globe, in which he introduced at once quite a number of new classes of maps, mineralogical, meteorological, climatological, hyetographical, palæontological, tidal, and moral, which twenty years before had not been dreamed of. New fields of investigation were opened in every direction, and we began dimly to foresee of what further development this new art was capable.

If it be asked now, with respect to our special object, whether we should include in our collection not only the commonly so called geographical maps and charts which have been made from olden times, but also all these new physical, moral, and other maps of recent invention, I believe there can be no doubt that we should answer this question in the affirmative.

What reason could be given for admitting the old and rude sketches of coast lines, river courses, and mountains, made from the time of Columbus, and which form only a very small part of what constitutes the body of a continent, and excluding all the equally useful and necessary pictures of the distribution of its animal, vegetable, and mineral contents? Why should we be satisfied with the mere outlines of the political boundaries of states, provinces, counties, and cities, when the Indian tribes, European races, languages, customs, manners, crimes, diseases, &c., are equally subject to geographical distribution, and can be delineated with the same precision and clearness?

With Columbus commenced the hydrographical discovery and chartography of America. The *geological* discovery and chartography of America began only a few years ago. Our first geological maps of America of this century were as rude as the hydrographical maps of the beginning of the sixteenth century. For some parts of the continent they have been greatly improved, for other parts they are still in the first stage of development, and for many they do not exist at all. These geological maps are now just as much scattered through all sorts of books, offices, and depots, as were the hydrographical maps of the olden time; and unless we make complete collections of them now, while it is possible, the rapid progress of science will cause them, in like manner, to disappear. They are equally valuable, moreover, as scientific documents; they mark the point at which we have arrived, they show what still remains to be done, and they serve as a solid basis to build further upon hereafter. If we should collect and preserve the one class, there is no reason why we should not likewise provide an asylum for the other; and why we should not, by an historically and chronologically organised collection of all the attainable geological maps of America, enable our successors to trace the progress of this department of knowledge step by step?

And what is true as respects geological maps, holds good also with regard to the botanical, zoological, magnetical, ethnographical, and other numerous classes of maps. Each of them has had its beginning, each has inaugurated a discovery of America in a new sense, and each is capable of progressive and indefinite improvement.

I therefore do not hesitate to pronounce that we should collect and register every map of every description on which a successful attempt has been made to depict any feature of the country that is subject to geographical influences, and is capable of being more accurately conveyed to the mind by means of colors and lines than by mere verbal description.

IX.—ON THE CHOICE AND SELECTION OF THE MAPS.

There can scarcely be a doubt that we should aim at completeness in our collection of former American maps. This, it is evident, should be a guiding principle, if our collection is to become essentially useful. We should have of every part of the continent a connected series of representations, which will explain each other, because they have grown out of each other.

Nevertheless, though completeness ought to be our aim, still it is evident that this completeness must have its limits. The number of maps which have been published of the New World and its parts is so extremely great, that the labor of procuring them all would be enormous. At the same time, the value of individual maps is so very different, that while some form more or less essential links of a complete chain, others are so valueless for the purpose contemplated that we may, without regret and without loss, refuse them admission to our collection.

It is necessary, therefore, to make a critical selection; and to guide our choice in this respect, we may first divide all the maps that present themselves for admission into two great classes, namely, maps made by discoverers, navigators, and travellers on the spot, and maps which were afterwards composed at home, from the original sketches, by official geographers and learned map-makers. In selecting from that most interesting class of documents, maps from actual survey, we should use great caution in rejection, while a certain severity of criticism is allowable and even demanded in admitting maps formed by compilation.

When an explorer penetrates into a new and hitherto unknown region, everything that he hears and sees, all that he collects and puts down in his journals and maps, has an especial interest. However rude his draughts may be, they comprise all that is known of that region for the time being. They are liable to be copied and imitated a hundred times over, and in this way often become of high historical interest, even when in many respects false, on account of the influence they have exerted on the geography of their age.

Thus, to take a very striking example, the famous Baron La Hontan was certainly, in many respects, but little entitled to credibility. He composed, and published in his work, a very fanciful map of one of the great western affluents of the Mississippi, and of another adjoining river, flowing towards the west, to a supposed great salt lake. According to his own statement, he drew this map partly from actual survey and partly from a report, and a sketch on a deer skin, given him by his Indian friends. This map departs very widely from nature, and yet it is a not unimportant document in the history of American geography. As the baron was a bold and enterprising traveller, who soon became celebrated throughout Europe, his book and accompanying maps were repeatedly published, and attracted so much attention that thousands implicity believed what he reported of regions which were not visited again for a long time after. His fanciful map was adopted by geographers, copied many times, and inserted in all the maps of America of that time. We could not understand these maps without a look at the original draught of Baron La Hontan, which was the source of all those erroneous conceptions. Even as late as the latter part of the eighteenth century, we find maps reproducing La Honton's great river and salt lake. In a documentary history of American geography, therefore, this map, which, erroneous as it was, exerted so great an influence on map-making, should, by all means, find a place.

The same principle is applicable to many similar cases, as, for in-

stance, to all those rude sketches of interior parts of America, which, on different occasions, have been drawn by the Indians on skins or the bark of trees, and which sometimes were the first guides, by the help of which Europeans were enabled to find their way. Such Indian maps have often been considered as conveying very valuable information, and, consequently, have been sent home to England or France by governors of provinces, have been copied by European geographers into their works, and have then been deposited as valuable documents in the archives of state, or have been found worthy, as historical curiosities, of being preserved in the British Museum and in similar splendid collections. Nay, there are still some parts of America, as the interior of Brazil and Labrador, and the vast territories of Hudson's Bay, which are delineated on our maps on no better authority than that of an Indian sketch or report. It is evident, then, that we cannot neglect the study of these aboriginal productions, but must give them also a place in our collection.

If we now turn our attention to that large class of maps which have not been made on the spot by travellers themselves for the sake of perpetuating their discoveries, but which have been compiled at home, either for general instruction or to serve the purposes of commerce and navigation, we must begin by subdividing them into ancient and modern maps, and, with respect to their authors, into those which have been constructed in the cabinets of scientific individuals, or in hydrographical and topographical bureaus, and those which have been made in map manufacturing establishments, by the traders and copyists who live on the knowledge of others. Some of the old maps, which have been compiled by careful students of geography, have nearly as much historical value and importance as original maps from actual survey, nay, sometimes more.

Ribero, the celebrated cosmographer of the Emperor Charles V., compiled in the year 1528 a map of America, for which he used the actual surveys and draughts of different discoverers, which at that time were still extant in the marine depots at Seville. Ribero laid down on his map the coasts of North America after the drawings sent home by Columbus, Ponce de Leon, Cortes, Garay, and other Spanish navigators and conquerors. He traced the coasts of Peru, so far as they were known in the year 1528, by the progress of Pizarro. For the coasts of Venezuela, Guiana, Brazil, and Patagonia, he had before him the charts of Pinzon, Cabral, Solis, Magelhaens, and many other Portuguese and Spanish explorers. Of the original maps and actual surveys of all these celebrated men nothing or very little is now left to us; but by a careful anatomy of the map of Ribero, and by resolving it into its elements, we could to a certain degree supply our want of sources from which it was compiled, and restore to each explorer what originally belonged to him.

The same may be said of many ancient compiled maps which we find scattered through the editions of Ptolemy, or in the works of Ramusio, Munster, Mercator, Ortelius, and many other diligent collectors, who were never themselves in the field, but whose compilations give us more or less faithful copies of actual surveys, and serve us in their stead.

It is evident, then, that the older a compiled map is the more original matter it may be supposed to contain, and that often the entire picture in all its parts will be unique to us. But even later maps may sometimes have the same value, at least for certain parts of their contents. The famous and interesting globe of Molineux, in the Middle Temple in London, is in many respects only a copy from copies of other well known maps. But for certain northern parts of North America, Molineux had before him the original draughts brought home by Drake, Baffin, and other English navigators. He copied those draughts, and transferred them to his globe, which is now the only authentic thing in the way of maps transmitted to us from those navigators. That part of Molineux's globe, therefore, possesses for us the authority and value of a most precious historical document. In such a case we should copy if not the whole at least the most important parts of the map to be inserted in our collection.

But neither should all the works of compilers who had few or no original documents before them be rejected by us, if that is true which a biographer states of the great French map-maker, D'Anville. "D'Anville," he says, "combined with vast information a very fine and experienced eye. In the enormous mass of materials offered to him for the construction of his maps, he quickly discovered the right from the wrong, and seemed sometimes by a kind of critical instinct to recognise the truth." D'Anville's maps, therefore, were not mere compilations; they were new creations. By adopting the mean of all the differing lines offered to him, which were all wrong, he drew upon his map the correct line, and thus produced something new, which was truer than all the rest.

Such men as D'Anville gifted with such a decided genius for geography are rare. But they appear sometimes, and then they generally correct so many errors, discard so many old prejudices, and base their productions upon such a solid foundation of truth, that they become the models and guides of their successors, as if they had been discoverers themselves.

The old cosmographers of the 16th century, Sebastian Münster and the still more excellent Ortelius, were men of this stamp. They first led the way in map-making and geography, and were called the Ptolemies of their age. The maps of Ortelius, in particular, served as the basis of all the similar works undertaken after them.

Hondius, Blaeu, Nicolaus Vischer, Sanson d'Abbeville, and Duval, among Dutch and French geographers, took the lead in this branch of science and art during the 17th century. Sanson d'Abbeville has been called the creator of geography and map-making in France.

Delille and D'Anville, in the 18th century, effected great improvements in the maps of their age, although not travellers themselves, merely by the help of critical study and sagacious combination.

Such men as these, whom I mention only as instances, possessed the confidence of their governments. To them were laid open all the materials concealed in hydrographical and topographical archives. They made themselves masters of this undigested matter; and because they put on their maps no line, point, or name about which they had not studied everything within their reach, and for which they had not

the best existing authority, their works must be considered as the very type of the knowledge of the age. Their maps make an epoch for every country which they touched upon, and may sometimes preserve to us features for which every other authority is lost.

It is observable in the history of every art, but especially in the art of map-making, in which so much indolent and servile copying has been going on, that the real work is done by a comparatively few inventive and ingenious minds; and it must be our particular care to find out those men and those maps which, in any respect, have taken the lead.

Sometimes we cannot use all that such a man has left us, but only a few of his productions. Thus, for instance, we would not use all the maps of Hondius; but to leave out those which he composed of Guiana, for the discoveries of Sir Walter Raleigh, or for the voyages of Drake and Cavendish, would be an unpardonable omission.

So, too, we might dispense with most of the maps of the French geographer Robert de Vaugondy; but we ought not to neglect his atlas of the Arctic polar sea, which gained him so much celebrity. In the same manner other geographers, like the painters, had their favorite subjects and their master-pieces. Only a few, like Ortelius or D'Anville, deserve that everything they produced should be collected.

With some we must not be content with a single edition of their maps, but must endeavor to procure them all; because each issue was carefully revised and augmented with new discoveries, so that every one of these additions is a mark of progress.

The productions of the few great and learned geographers who took upon themselves the painful business of map compiling were afterwards, when once published, copied and recopied by a host of manufacturers of all nations A D'Anville was edited and re-edited in England, in Germany, in the Netherlands, sometimes tolerably well, and sometimes very ill; sometimes with additions and so-called corrections, and sometimes without; sometimes under his own name, and sometimes under the name of his plunderer. And frequently these copies were copied again in distant countries; and thus the light which D'Anville threw on the configuration of our world, became at each remove from the original more diffused and obscure.

To adopt into our collection all these copies of copies would be worse than useless; though even here an exception may occasionally be made. Some mere map manufacturers were so very active, and managed to introduce their productions so generally into the market, that they played from this very circumstance an important part in the history of geography. They were introduced into schools, libraries, commercial towns, and even into the ships of navigators. They exercised, not a very well deserved or beneficial, but a very important influence on the spread of geographical knowledge, and even on navigation and the progress of discovery, and they therefore must not quite escape our attention.

Numberless maps have been constructed, not merely with want of care, but with the evident intention of falsifying geography. The reasons for doing this have been manifold. Sometimes learned men have represented the position of places or the configuration of coun-

tries falsely, with the view of sustaining a geographical hypothesis. Explorers, too, have often committed this sin, in order to add a little to their glory, by magnifying the extent of their discoveries, and especially by carrying them to a higher latitude than had been done by others. Maps have also been falsified officially by governments, either for the purpose of concealing from foreigners the assailable points of their territories, or for giving to their boundaries a greater extent.

Even such false representations should often be comprised in our collections, especially when they may still become the object of some important scientific or political discussion.

Falsifications of maps at the instigation of trading associations, railroad companies, and other speculators, are also not rare. On one occasion a map was published of the State of Maine, liberally furnished with an assortment of fabulous rivers, which were represented as navigable to certain points; and all for the purpose of enticing land buyers, wood-cutters, and settlers to those localities. With such fabrications we, of course, have nothing to do.

XIII.—ON THE ARRANGEMENT OF THE COLLECTION.

It is evident that a mere accumulation of some thousands of maps without order would be of little or no use, because in every case in which we wanted to refer to them the trouble would be enormous.

What principles, then, are to be adopted for bringing order out of this chaos?

If we had here to treat only of a narrow spot, of a limited country, then a simply chronological arrangement would be sufficient. But having before us a large continent, more or less connected with all the rest of the world, composed of many extensive regions, and containing numerous important rivers, harbors, and cities, an adherence to the chronological order alone would be far from satisfactory. If the maps of Canada were mixed up with those of Patagonia, and the special surveys of the harbor of New York with the general maps of America, according to their time of publication or composition, the trouble of search would still be immense whenever we wanted to consult the maps with respect to a certain point.

Hence it is evident that, while a *chronological* arrangement should pervade the whole, *geographical* distribution should be resorted to for reducing the collection to manageable subdivisions.

In accordance with these views, we would propose to put in an introductory class all those old maps of the world, by whatever nation produced, in which some indications or conjectures may be found as to the existence of islands and countries beyond the limits of the known old world.

When the new world was discovered, the mind of the European public was at first principally occupied with the general questions as to what this country might be, how far it might extend, and in what relative position it might stand to the rest of the world. Far-reaching voyages were undertaken, in order to ascertain the great outlines of the whole, before attention was directed to the study of the particular

parts. For a long period, therefore, scarcely any but *general* maps of the entire continent were produced.

It is proposed, then, that the second class of our collection shall consist of those general maps of America which show us the configuration of the continent, its position on the globe, and its relation to the other parts of the world, as these were gradually developed by years of exploration and study.

It is only in our time, as it were, that America has been fully circumnavigated and its general features completely made known. We may therefore bring this division of our maps down to these latter years; though, of course, among the enormous mass of modern general maps of America, only those should be selected which really exhibit some important change in the general outlines.

Since the geographical pictures of the northwestern part of Europe and of the northeastern part of Asia belong, in a certain degree, to a collection of American maps, because these countries approach the new world, and were for some time thought to be connected with it, the old maps of these countries down to the time when this supposed connexion was disproved will form two lateral and supplementary branches of our collection of the general maps of America.

America was at first supposed to consist of two separate islands or continents, afterwards discovered to be connected by a narrow isthmus, which we call North and South America. These two great bodies of land belong to opposite hemispheres of the globe, are separated from each other by broad waters, offer many contrasts in their physical features, and have had, to a certain extent, their separate histories; consequently they have in general been treated separately by geographers. This circumstance gives occasion for a third and fourth division of our collection—one of which will comprise all the maps of the northern, and the other those of the southern continent.

North and South America are each subdivided by nature, as well as by history, into different large portions. According to the principle of division adopted, we might dissect them in almost numberless ways; but for various reasons it would seem best to submit in this respect to the dictates of custom, and follow the practice pretty generally adopted by map-makers, geographers, and the public at large.

It is customary, for instance, to use the term *Russian America* as the name of that broad northwestern peninsula of the continent which is possessed by the Russians. In adopting this name we follow as a principle of division the dominant nationality. Everybody knows what is meant by the *Arctic regions* of America—a name derived from the position of these regions on the globe; and nearly all geographers adopt the division of Canada and Canadian maps, which designation is derived from the political name of the country, and comprises, more or less, the maps of the great St. Lawrence basin. Another division has been made of the Mississippi valley; though this forms only a hydrographical whole, and does not correspond to a political partition. Brazil, Patagonia, Peru, &c., are other great names which everybody uses and understands.

We therefore adopt all these and other customary divisions, and

form the different classes of our map collection after them. Before enumerating, however, all the divisions which are thus obtained, it will be proper to determine the order in which they should be arranged.

America was first discovered on its eastern coast, and in its central parts, the Antillian islands. Thence discovery spread to the south and to the north, and after some time reached the western coast. The same direction that was taken by the discoverers was afterwards followed by settlement and colonization. The march of American history has been a movement from east to west, and from the centre towards the north and south. Upon the whole, therefore, we shall arrange the divisions of our collection in the most natural way, by pursuing a similar order. They will thus succeed one another as follows, viz:

1.—*North America.*

1. The Antilles and Caribbean islands.
2. Mexico and Central America.
3. The Atlantic slope and general maps of the United States.
4. Canada.
5. The Mississippi valley.
6. California, or the Pacific slope.
7. Labrador and Hudson's Bay countries.
8. The northwest coast of America.
9. Greenland and the Arctic regions.
10. Russian America.

2.—*South America.*

1. Venezuela and the basin of the Orinoco.
2. New Granada and the Magdalena river.
3. Guyana.
4. The river Amazon.
5. Brazil.
6. Peru.
7. The Rio de La Plata and Paraguay.
8. Chile.
9. Patagonia.
10. The Antarctic regions.

It is evident that this arrangement has its inconveniences. It separates, for instance, by a great gap the maps of the Antilles and the Caribbean islands from Venezuela, which lies in fact so near to them. It separates also the Arctic and Antarctic discoveries, which approach each other in respect to time. But it is the only arrangement which we can come to, and is, I believe, less inconvenient than any other that could be proposed.

The geographical and political names which we have given to our twenty large subdivisions are, of course, not to be taken as very exact definitions. They must be considered as designating the regions only in a general way. Some of these names, especially the political ones,

have, at different times, had a very different signification. The name Canada, for instance, formerly covered much more, and that of the United States much less, ground than now.

No arrangement, however, that we can adopt will enable us, in all instances, to find under one head every map that is explanatory of a given country. We can only expect to find the *principal* things united under it, and must always be prepared to search somewhat in the neighboring divisions. Thus, if a person would study, with the help of our collection, the geographical history of the La Plata river, he must consult, besides the maps placed under that head, those also which are contained in the divisions of Brazil, Patagonia, Chile, and Peru; because, if not the whole, at least some branches of the river may at times have been represented under those heads. It cannot be expected that a collection like ours should altogether do away with trouble, study, and research, but only that research should be made *easier*, or rather we should say, in many instances, *possible*.

For the beginning, and for a limited historical collection of American maps, the divisions named would perhaps suffice. Whether these different classes should again be subdivided, and how far the subdivisions should be carried, whether to the history and chartography of every province, county, port, and town, would depend on the development given to the collection. That in many parts of America, at least, we might come down in a useful and satisfactory manner to very small divisions, there is not the slightest doubt. It might be useful to provide, at the very beginning, a special receptacle for the maps of some very important points, such as the harbors of Boston, New York, Havana, or Rio Janeiro.

A further question arises with respect to the place to be assigned to maps commonly known as physical, geological, zoological, tidal, current, wind, &c. Shall they be mixed up according to time and place with all the rest of the maps, or shall we make of them separate divisions? Shall, for instance, a geological map of Peru of the year 1830 be placed along with the topographical and political maps of that country of the same period?

If the geographers of America had, from the beginning, made geographical, geological, and all other descriptions of physical as well as historical and political maps, and if they had all been developed in equal degrees, and in parallelism with each other, then I would say that all the different species of maps of each part of the continent might be strictly arranged together according to chronology, as such an arrangement would give a better and fuller view than could otherwise be obtained of the whole growth of knowledge respecting that country.

But as the case actually stands, I believe it would be better to collect the physical maps separately—at least the greater part of them. Natural history is a very recent science, and the chartography of natural history is newer still—is only in its childhood. Political and so-called topographical maps we have in great numbers. Physical maps are still very few and scarce. They would be in a manner lost, if we were to combine them with the overwhelming bulk of the former. We have, for instance, some hundreds of topographical and political

maps of Russian America, but only one or two attempts at a geological survey of that country. If we should chronologically interlink the latter with the former class, we would always have much trouble to discover them again.

Then again, the American waters—I mean those parts of the ocean which belong more or less to this continent—have had different physical maps constructed for them, (such as maps of tides, currents, winds, &c.,) but never any political maps, (which, by the by, is a somewhat curious omission, as certain political divisions and limits on these waters might readily have been discovered.) How could we connect the physical maps of our oceans with those political divisions of the continent? I therefore believe that it is better to separate altogether the few physical maps which we possess from the topographical and political ones, and to collect them into special divisions. This could be done in different ways, either by forming an entirely separate body of the physical maps, or by forming them into a kind of supplement to each of the great and small divisions of the topographical and political maps.

If we should adopt this latter plan, then, under such heads as "*Mississippi valley*," or "*State of New York*," would first be given, in their chronological order, the topographical and political maps, and after them the botanical, geological, zoological, and others. This would afford the advantage of having the entire body of information respecting any one region in one and the same place.

But I believe the number of physical maps would be too small even for this manner of disposing of them. The physical features of the different regions have not, as yet, been figured much in detail. It is true we have not only general geological maps for the whole of America, but also now and then a special one for a State or some other smaller country. But for many other branches of natural science there exists either no map at all or only very general ones. Where, for instance, shall we find a zoological, climatological, or magnetical map of Massachusetts or Rhode Island? Many extensive regions of America are as yet so little known, that we are happy to have even their more general physical features traced in a more or less accurate way. If, therefore, we should make preparations for supplements to every one of them for the reception of their physical maps, we would often find nothing wherewith to fill these supplements. I think, therefore, that the best plan of proceeding would be to put the small number of our physical maps by themselves, and to prepare for them a special department, co-ordinate and supplementary to the great body of topographical and political maps.

If this be so, the question next arises, how should we organize this separate body of physical maps? Ought we to proceed here in the same manner as with the classification of the other maps? Shall we first collect the general physical maps of America, and then those of particular river basins, empires, States, provinces, &c. And shall we repeat this for each of the different branches of natural science—first, mineralogy, then magnetism, and so on?

The present state of our chartography hardly warrants the adoption of such a plan. For many branches of natural science we possess no

special maps of small territories at all; and for some, probably, we never shall possess them. Many natural features seem to sweep with a certain uniformity over a large tract of country; so that nobody has ever thought of giving us a special wind map of the State of Delaware or a zoological map of Long Island.

It is true that even in these extensive natural phenomena, which we now portray only with a broad brush, we may, in time, discover some regular local peculiarities worthy of being delineated on a map. In some cases we have already discovered such local variations. Recent observations have shown, for instance, that the deviations of magnetical attraction, even on such a circumscribed territory as the District of Columbia, are very great; and we may, in time, possess special magnetical maps of the District and of similar small localities. Modern observers again have shown how very peculiar and exceptional are the movements of the great tidal wave in such a small water basin as the Sound of Long Island, and they have tried to paint these peculiarities on a special tidal map of the Sound. Cases like these, however, are too exceptional to justify the adoption of such a plan.

For the present, therefore, we propose that all the so-called physical maps, to whatever science they may belong, shall be thrown into one and the same great division under the general head of *physical maps*, and that this division shall, for further convenience, only be subdivided into those twenty-one great divisions into which we have divided our topographical and political maps—that is to say into general physical maps of the whole of America, and then into physical maps of the Mississippi valley, Mexico, Brazil, Patagonia, &c. &c. To these twenty-one divisions we may then add five or six divisions for the physical maps of the American seas, which have found no place in the topographical collection, one for the Atlantic ocean, one for the Mexican Gulf, a third for the Pacific, and a fourth and fifth for the Arctic and Antarctic oceans.

There are still many other classes of maps, which we cannot well classify under the head either of topographical and political or of physical maps, or which, at least, we are not accustomed to consider as a part of either.

First, there are the ethnographical maps, pretty numerous in this country, where so many different native tribes are found. The names and localities of these tribes and of different other nations have often been put down on the general topographical maps; and thus ethnography is, to a considerable extent, included in those maps. But in modern times maps have been constructed whose especial object is ethnography, or the distribution of tribes and languages.

There are, also, the so-called moral maps, which exhibit the statistics of crime or of certain customs; others again try to give us the statistics and limits of the various diseases and other phenomena among men. Some show the denseness of population in the different parts of the country. We may comprehend all these under the general name of statistical maps. Some geographers, as, for instance, Berghaus and Johnston, have incorporated these ethnographical and statistical maps in their atlases and collections of physical maps. But it is evident that they do not properly belong there.

There are, again, the road maps, the object of which is to show the condition of a country as regards its turnpikes, railroads, canals, bridges, &c. Sometimes the land offices compose special maps, to indicate which parts of the country are taken up and which are still to be sold. The post offices have maps for their special purposes. Maps, again, are issued to show the number and distribution of telegraphic stations, of magnetical observatories, of light-houses, and for numberless other purposes, important for the administration of the government. These we might term official or administrative maps.

It would no doubt be of the highest interest to have all these maps collected and brought into a regular arrangement, according to class and time. But in these respects, chartography has only made its first steps—at least in most of the countries of this continent. It would, therefore, for the present, perhaps, be advisable to throw all the maps which we cannot place under the topographical or physical heads into one and the same great division by the name of "*miscellaneous maps*," which might then be subdivided into the three following orders: first, ethnographical, linguistical, and moral maps; second, statistical maps; third, administrative maps.

In course of time, when chartography should become more developed and the number of maps increased, we might form for each class and order a separate collection.

XIV.—LITERARY AID TO BE PROCURED.

What we propose seems to be, in some respects, a quite new and unusual thing. Maps generally have been either constructed as secondary works to serve other purposes, to illustrate the books of travellers, geographers, &c., or they have been collected in great chartographical works called atlases, which show all the countries of the world as they were known and depicted at a certain time. We propose to separate them from those books, to cut up those atlases, and, extracting those maps which we want for the illustration of our subject, America, arrange them according to the plan of our collection, where they will thus find themselves otherwise surrounded and placed in other connexions.

The question may arise, if in this way we shall not endanger the intelligibility of the maps, and likewise their usefulness; or whether we can suggest remedies to obviate, or at least counterbalance, these contingent disadvantages.

To diminish at the outset these and similar apprehensions, we may first observe, that many maps, both ancient and modern, have been issued in loose sheets, without other explanation, or needing any, but that contained in the maps themselves.

Again, geographical maps, it is obvious, have a double nature. They possess the advantage over mere pictures of being literary as well as artistic productions. They therefore can and generally do bring with them much of the materials necessary for their own interpretation. Even when connected with books, they admit, for the most part, of being detached without detriment; and this, perhaps, in a higher degree than many statues, pictures, &c., which nevertheless

we are accustomed to separate from their appropriate temples, palaces, churches, bridges, &c., without scruple, though only capable of being fully appreciated under their original and local associations.

Furthermore, it may be observed, that numberless maps have been added to books, with a professed intention of illustrating and being used in connexion with them, without possessing any real adaptation. Travellers have embellished their reports with maps which ought to have shown us their routes or illustrated the regions traversed, but which, to our great regret, have neither served the one nor the other purpose. We find sometimes in the maps certain descriptions and names, and in the reports quite unlike descriptions and quite different names. The same thing has often been done by historians, who have related one thing in their text and depicted another on their maps. In olden times many ancient maps of the world were added to books which contain no allusion whatever to the maps; for instance, to Bibles, to religious treatises, to old chronicles of some province or city, &c.

In all such cases, where the connexion of the maps with the works is merely a casual one, we may without scruple separate them. The maps will become more intelligible and useful by being admitted into our collection and finding themselves surrounded there by old relations and associates. The *shortest* notice which we may add to our copy or detached sheet, about the place or book from which it was taken, will sometimes suffice to make amends for the whole loss sustained in the separation.

In cutting up atlases and other collective works of maps and distributing them through our collection, it is true, we dissolve sometimes a beautiful piece of art into its elements, and, at the same time, we deprive the isolated maps, to a certain extent, of that light which they receive when they are considered in connexion with those collective works.

In old portulanos, for instance, the title-page and introduction contain sometimes very curious, valuable, and characteristic hints and materials respecting the geographical ideas which presided at the construction of the work. Nay, the very frame-work and the covers of these portulanos contain paintings and allusions for illustrating the spirit of the times in which they were composed. Besides, in taking the whole portulano, or atlas, and comparing each part with the other, we learn much that will serve for deciphering the handwriting and for better understanding the different signs made use of.

As a counterpoise to these objections, it should be considered that if our maps lose some elements of intelligibility by being separated from their old companions, *they receive quite a new light from those with which we associate them.* If a portulano by being cut up loses something as an *artistic* work, it may be greatly enhanced by our process in *scientific* and *historic* importance; and then that light which the maps of the same work threw upon each other in their original connexion need not be quite lost by their separation. By means of notes, or the catalogue, it will not be difficult to point out the region of the collection where the related maps can be found and reference be had to them.

But how shall we deal with those maps which are designed as genuine illustrations of a literary work, and are so interwoven with it that map and book seem to form one inseparable whole, but which, at the same time, would seem to be an indispensable complement to our proposed collection?

Cases of this kind must be numerous; whether in the instance of discoverers and travellers, whose maps and narratives are sometimes mutually explanatory, or in that of historians, whose plans and diagrams can only be satisfactorily explained by the work for which they were specially composed. Again: there are numerous scientific maps—geological, magnetical, hyetological, and others—which can be thoroughly understood only in connexion with their respective works, and which nevertheless would fill a place in a series of pictures representing to the eye the progress, development, and present state of those branches of knowledge.

The statement of this objection shows that it cannot be our intention completely to dispense with literary help or renounce the assistance of books. On the contrary, as we now proceed to announce, we must have the books too; our scheme must include a library of a certain extent and character. Our intention has only been to insist that the chartographical documents should be put forward as the principal thing, that they should not be mixed up with the books on the shelves, or be deposited in corners of the library, as is their usual fate; but that they should stand before the eye as the prominent and independent object of the collection. This plan excludes the books only from our chief and central compartment. It by no means refuses them admission as auxiliaries, or denies them the shelter of a side-room in our establishment. In fact, our chartographical institute will stand so continually in need of books of reference of various kinds, that we would propose to lay the foundations of such a collection from the very commencement of our enterprise. Its nature, limits, and manner of arrangement, ought therefore to become an object of inquiry from the first.

This auxiliary library, then, should first contain the historical works and books of travels from which we have taken maps, and which are necessary to explain these maps. Further, it should contain all important works on the subject of American discovery, geography and history, and at least some good dictionaries of those languages in which the legends on the maps have been written; always, however, keeping in view the subordinate character of the collection, and restricting it to what is clearly indispensable.

Still more to circumscribe the requirements of our library, we have yet other means, which the nature of our maps suggests to us. We propose to append to every map that may require it certain notes touching its history, origin, and value. How this may be done in an efficient and tasteful manner I propose to show in the following section, where I treat of the principles on which the exterior arrangement of our collection is to be made.

Here it may suffice to observe, that only in this way probably can the inspection of any map be made in the highest degree useful,

namely, by bringing at once and on the same sheet before the eyes of the inspector nearly all that he can require.

If he wishes to enter more deeply into the subject, if neither the examination of the map alone, nor the comparison of it with precedent and subsequent maps, nor our notes should satisfy him, then we must refer him to our library; for anything beyond this he must, of course, look to the treasures of science at large, to the great libraries and scientific depots of the learned world. A collection like ours has fulfilled its duty, and sufficiently asserted its right to exist, when it brings to some degree of concentration and perfection a well defined class of documents for the elucidation of the history of the American continent.

XV.—EXTERIOR ARRANGEMENT.

As the interior organization, so also the exterior arrangement, of such a comprehensive collection of documents as we propose, has its difficulties, particularly because it will be a changing, progressive, and growing collection, and we must be prepared for a perpetual and rapid increase.

The principal law of such a collection ought therefore to be, that, although it is necessary at once to classify and organize, (for without this, our little collection could not be rendered immediately useful,) yet we should not make too permanent and unalterable preparations. *Pliability must be the principal quality of our arrangements.*

The first consequence dictated by this law would therefore be that the rooms assigned for our collection should be a little more spacious than would be necessary for the number of maps which may be deposited there at first. Yet they need not and ought not to be very lofty, because the receptacles for the maps should not be so.

These latter should not be higher than a man, so that the maps could be reached easily, and handed down with one short movement to the tables of exhibition, which in all cases should be near the respective depots. The use of ladders, staircases, &c., should be altogether dispensed with.

The repositories of the maps should, therefore, along their whole range be accompanied by a series of broad tables on which to exhibit the maps. The space between these ranges of repositories and tables must be a little broader than is usual in libraries, in which the objects to be exhibited are generally smaller. A particular attention should be given to light, and this point is with us even more important than in libraries, because maps offer often very minute objects, slender lines, and fine handwriting. In a word, well lighted, spacious, and not very lofty rooms, would meet all the necessities of such a collection as we propose.

In some chartographical depots the system has been adopted of making every map into a roll, fastened with strings. These rolls are labeled on one end, and on the label is written in brief the title and number of the map. The rolls in every class or division of the collec-

tion are placed in such a way that they turn their labels towards the interior of the room.

This arrangement has the great advantage, that when one particular map is looked for it is not necessary to take out the whole parcel to which it belongs, and to search for it among many other maps. Each document can easily be selected by looking over the labels, without disturbing the rest.

On the other hand, however, this manner of arrangement, which is observed in nearly all the American chartographical collections, and which is excellent for their particular purposes, offers for ours some great disadvantages.

First, the maps when they are rolled, and still more so when each roll is put in a separate cylindrical box, as is done for protecting the maps in the archives of the United States Coast Survey, take up a much greater space than when the plain sheets in their flat state are laid one over the other. We can easily put in one case of a moderate size a hundred maps, sheet over sheet, while perhaps six times as much space would be required if we rolled them. Besides, the rolling of the maps, the unrolling and flattening them, the troublesome fastening of the little bands, &c., have their inconveniences, and the maps must be particularly prepared and strengthened for these often repeated processes.

But the principal objection is, that the rolling system would be directly against the spirit and tendency of our historical collection: this being destined to show how the maps grew out from each other, it will often happen that a whole series of connected maps is to be consulted. Here it is essential that the chronological order of the maps in every division should always be preserved, which might be difficult in the process of unrolling, since maps thus managed would always be liable to interfere with one another, and thus get into confusion.

I am led therefore to the conclusion, that our maps ought to be deposited flat in broad, commodious drawers, one above the other. Labels with numbers and titles may always be added to each of them, in case it should be considered requisite. The drawers will only serve as a receptacle; for carrying a whole division of maps out of them, and for moving them to the tables for exhibition and back again to the drawers, they may besides be surrounded by a portfolio of pasteboard.

In no way, however, should our maps be bound up like the sheets of an atlas or a book. They should, in the beginning at any rate, be kept as loose sheets; because, as has been said, the whole collection must be pervaded by a spirit of progress and growth, and each article be prepared at any moment to cede its place to another newly introduced. Every map should also be ready for being transferred from one class into another, and every class for separation into two or three other classes, if the richness of materials in any division should be such as to authorize it. Even the more ancient deposits of our collection should be kept, at least for some time, in the same movable state; because the archives and libraries of Europe might always throw up some old map which had escaped our attention. Sooner or

later, however, for some division, (for instance, the old maps of Scandinavia, or those of Northeastern Asia, or the maps of the world before Columbus, or the general pictures of America of the 16th century,) there may arrive a time when we can deliver the loose sheets to the binder, and form a finished and complete atlas of them, finished and complete at least for a certain period and for a certain class. The same may be done with propriety even in some branches of our collection which are subject to perpetual changes and additions, when we have carried these branches to their complete development through a certain period. If we are sure, for instance, on the appearance of a very excellent map of the harbor of New York, that we possess pretty much all the other preceding surveys, we may then connect and bind them in a volume in chronological order, and may begin anew to collect the following surveys for a subsequent volume. With these different volumes and atlases, then, we would have at least reached that useful and manageable form of exterior arrangement at which we aim in regard to all our geographical documents.

Having now shown, in a general way, what external accommodations we want, it remains still to inquire how every particular sheet should be treated, to make it most serviceable to our purposes, and to prepare and strengthen it for the most lasting use.

We have already shown, in a previous section, that with the map itself a concise sketch of its history and origin and an indication of its principal contents should be given on one and the same sheet. The question arises, in what manner this ought to be done.

The maps, especially the ancient ones, have sometimes very curious titles, given to them by quaint old writers. If we should give to a map only this title, nobody would at first know what country was meant by it. Sometimes the strangeness of the title arises from the primitive but now obsolete names given to different countries. But besides this, the titles of the maps are given in all sorts of languages, in Latin, Spanish, Swedish, Dutch, &c. To apply only these titles to our maps, and catalogue them under the same, would be very inconvenient for English readers, for whom our collection is principally destined. Therefore, all the titles of our maps should be in plain English, and the countries, oceans, and other principal objects, should bear in the added title the names by which they are now generally known among English geographers. Otherwise, who would know, for instance, that by the title "Tabula terrae Stæ Crucis" (Picture of the Land of the Holy Cross,) was meant Brazil, that "A Map of the Country of Parrots," represented the Antarctic regions, or that "Peruviana" was but another name for South America?

To the general title of the map the year of its production and the name of the author should be added. If we do not know the year, at least the century to which the map belongs should be indicated; and if we cannot find out the author we should, at any rate, designate the country in which the map was composed, as "French map," "Spanish map," &c. Nor should the old original title of the map—though we cannot make use of it for the purpose of speedy reference and of cataloguing—be omitted; while there should also appear on the map itself some more explicit information about its origin, and

some further criticism about its contents, by which the examiner might be guided in his researches.

To procure space for these remarks and notes, we propose to paste each of our maps on a broad sheet of strong paper, which would leave a margin on both sides, where we could fasten narrow slips, on which the short explanatory notes here spoken of might be introduced. In addition to the original title of the map, they might contain brief observations on its author, some remarks on its value and principal contents, the position which it occupies in the whole series, what additions and improvements it contains, &c., &c.

The slips on which these notes are to be written should be of white paper, like the map itself. But we should prefer, for different reasons, to paste the slips, as well as the map, on paper of a grayish color. First, the contrast of the vacant and neutral-tinted margin with the strikingly white maps and notes attracts the eye at once to the principal things on the exhibited sheet. Then the grayish color is not so subject to be spoiled by frequent use. Moreover, in this way we bring our maps as nearly as possible, and as far as the necessary considerations of space will allow, to the exterior appearance of pictures. There will thus be presented a somewhat attractive variety of colors; not glittering, and strongly contrasted, but suitable to the serious character of the collection. Nor should this consideration be deemed unworthy of attention. The study of the old maps has been neglected in some measure from their want of attractiveness of appearance. To engage attention anew, then, we should call to our aid such modest embellishment as taste and the nature of the object will allow.

XVIV.—REVIEW OF UNDERTAKINGS SIMILAR TO THAT PROPOSED HERE, AND CONCLUDING REMARKS.

Similar propositions to that which we have here laid before the reader have already been made, and similar projects have been, at least to a certain extent, realized, at different times.

We may regard as the very first of these attempts the collection of American maps and reports, so frequently alluded to, which Ferdinand, King of Spain, established at Seville. Had this institution continued to be conducted in the way in which it was commenced by its judicious founder, had all the American maps and sketches from actual survey been deposited and preserved there as in the beginning, it would now comprise the most valuable collection of American chartography extant.

In the year 1713 the excellent and well known Bishop White Kennet made to the Society for the Propagation of the Gospel in Foreign Parts a proposition which in many respects resembles our own. In the introduction to his excellent catalogue of American books and pamphlets, entitled "An Attempt towards laying the Foundation of an American Library," he propounds his plan so clearly that I cannot refrain from speaking of it a little more fully.

Like myself, the worthy bishop made for his own use a little collec-

tion of documents relating to the regions of the New World and to expeditions and voyages made to various coasts, ports, and rivers of the same. By and by he discovered, as he expresses himself, "a certain affinity of the arguments and matters," and "a certain dependence of things and places upon one another." He then proceeded to gather "other works as well of ancient as of modern geography, of astronomical observations, of experiments in hydrography, of shipping and the progress of navigation, of commerce and exchange, of war, embassies, voyages, and travels."

He finally presented this collection to the said society. But he wished that the place destined for it might be capable of receiving a much larger accession of books, globes, maps, sketches, drawings, &c., the future donations of other generous hands. For this enlightened man already saw (what the geographers of our time have urged repeatedly in vain) the necessity of an American central institution for collecting all new discoveries and contributions.

"Not only the missionary, or the merchant, or the historian and the herald might apply for information to such an institute; nay, even the greatest ministers of State might please to think that such a repository of papers of navigation and commerce might at one time or other be of advantage in the most arduous affairs of the kingdom, particularly iu asserting our dominion of the seas, in keeping up the wonted superiority of our fleets and navies, in securing and encouraging our fisheries and manufactures, in forming and maintaining our treaties and alliances."

"Among the uses to be made of this American collection," he goes on to say, "I ought not to forget that it is capable of becoming the common fund and treasury of all the remains of that country and of all the following discoveries and remarks that shall hereafter be made upon it. In such a fixed repository some modest mariners and travellers may lay up their own observations on the geography and natural history of those ends of the earth—of the climates, soils, seasons, winds, tides, waters, and other commodities. It may serve to pick up especially all the descriptions of coastings, bearings, soundings, sands, shelves, rocks, tides, journals and maps of voyages, travels, and adventures, and all manner of experiments now lying in a thousand private hands of mariners, merchants, strangers, who understand nothing of them, and would take but little care to preserve them from fire and consumption."

Thus clearly was the same idea developed a century and a half ago which we have been again presenting to the public. Our own plan differs from that of Bishop Kennet only in this respect, that our principal object is American *maps*, which have been so greatly neglected; while he had likewise in view the printed books, tracts, and pamphlets, for which since more sufficient provision has been made.

The excellent German geographer, Ebeling, appears to have anticipated our design still more nearly. He collected maps and geographical sketches: he cut them out from books and atlases; and he arranged them according to time and locality in the same manner as we have done and wish to do further. He, however, had not America

exclusively in view; he paid also less attention to the *original* sketches of the discoverers, and did not go with his collection as far back into former times as we wish to do. He admitted only such general maps of America as were printed and which he could purchase. He procured no copies or fac-similes of those unique maps which cannot be had in the original.

From Ebeling to the present time I know of no one who has made a similar attempt or proposition, with the exception of Lieutenant E. B. Hunt, of the United States corps of Engineers, who, in the year 1853, brought before the American Association for the Promotion of Science a project for establishing a geographical collection as a distinct and independent department. He wished it to embrace "all materials illustrating the early and recent geography of the United States, both its sea-coast and interior, including traced copies of all valuable maps and charts in manuscript and not published; also, the materials for illustrating the past and present geography of each State, country, township, and city," and, in the same manner, "all the maps and charts on the remainder of America. Further, the admiralty or sea-coast charts of all the European and other foreign States, and the detailed topographical surveys of their interiors—at least the most approved maps published from private sources, whether as atlases, nautical charts, or naval maps, including publications on physical geography, guide-books, railroad maps, and city handbooks." Further, Mr. Hunt wished to combine with the above a complete series of the narratives of voyages of discovery and exploration, besides geographical, geodetical, and nautical manuals and treatises, with all the requisite bibliographical aids to the amplest geopraphical investigation.

Mr. Hunt's primary object in advocating the formation of this collection was to provide for the wants of Congress; but, at the same time, he wished that it should furnish facilities to the State Department, the Bureau of Engineers and Topographical Engineers, the Coast Survey, the National Observatory, and the several naval bureaus.

"The value of such a collection," says Mr. Hunt, "in its relation to legislation, in its illustration of river and harbor questions, in its prospective use for illustrating history, and generally as a means of exalting and correcting our geographical knowledge, gives it most truly the character of a national enterprise."

Of all the plans and propositions of this kind of which I have any knowledge that of Mr. Hunt comes the nearest to my own, as well in the objects aimed at as in the means by which he desired to effect them. My principal deviation from his plan consists in this, that the collection I propose shall be as exclusively as possible *American*. American maps are what is wanted the most, not only here but everywhere, because they have been until now the worst provided for. At a later period we might try to include the whole world; but such a work is too enormous to be undertaken at once.

Further, Mr. Hunt proposed a general geographical department, and wished to put library and maps on the same footing; whilst I desire, at least, to begin with a mere chartographical depot, to which a small library may be added, as subsidiary merely; and this, too,

for the same reasons, because it is so very necessary to do something s quickly as possible for the *maps*.

It is sad to think, that of all these reasonable and useful propositions not one has been successful. Nevertheless, this want of success cannot prevent it from being brought forward, if necessary, again and again, until at length the time shall arrive when, all minds being prepared for it, the question will be carried unanimously.

Still, it is highly desirable, for various reasons, that the thing should be done at once. Destructive time is continually at work, and the gradual but never-ceasing progress of decay bereaves us daily of the most valuable documents, which can never be replaced. A hundred, nay, fifty years ago, we had still many of these treasures left, which, by carelessness and inattention, are now lost to the world. Even the early maps of these very young States are sometimes of the greatest rarity; and the first surveys of counties which were organized within the memory of people still living are, in some cases, no longer extant.

Besides the rapid diminution of the number of documents, the growing taste for collecting them makes them daily less accessible by enhancing their price. Rare old books, tracts, and maps, formerly but little cared for except by a few amateurs, are now sold in Paris for five and ten times the price which they brought twenty or thirty years ago. Any one who has been at all attentive to the movements of the literary market will have observed the same phenomenon in London, in Germany, and in other countries.

This general increase in the price of historical documents has, however, been in no department so enormous and striking as in that which relates to the history of America, probably because American books, tracts, and maps, as the records and monuments of mere colonies, were formerly the least esteemed of any, and because, in consequence of the transformation of those colonies to first-rate independent powers, they are now found to be of the highest importance. Nearly every new catalogue or report of a booksellers' auction gives us new proofs of this fact.

A work by one of the first American missionaries—the celebrated Eliot—which a few years ago could be bought for a trifle, produced recently at an auction in the city of New York the sum of two hundred dollars. A Spanish manuscript map of America, which the distinguished Baron de Walckenaer purchased for a small sum at the beginning of this century, was contended for at his death by different nations, and at last sold to the Spanish government at a price exceeding two hundred pounds.

Such facts, of which numberless instances might be given, speak a clear language. And we cannot yet see where this movement will stop. It will, no doubt, go on until old American documents and maps become scarce and valuable as the most precious gems. We thus find ourselves in the position of the famous Roman king. Time, like the sybil of the ancient story, destroys each year more of these venerable leaves, and, while thus diminishing the number to be disposed of, enormously enhances their price.

Besides the fearfully augmenting scarcity of old American docu-

ments, there is still another fact which makes the proposed plan every day more difficult of execution, and which finds its cause in the peculiar position of this country. The features of the old countries of Europe are already well known, and it is easy to combine the comparatively small portion of novelty which is brought out with the long settled facts. But in America, geographical discovery is still every day at work. Each hour brings us something new. Every travelling report, geographical work, or map, which is published, shows us new features, and corrects old ones or represents them otherwise. The exploring expeditions performed by government officers, by railroad companies, and by private travellers, extend every year further to the west, to the south, to the north. Of late years Americans have gone where they never did before—to the vicinity of the North Pole, and at the same time they have explored and re-explored Chile, Patagonia, and the Antarctic seas. The great valley of the Amazon has become quite a fashionable route for American enterprise, and the bosom of the Pacific has been furrowed in every direction. The great topographical, geodetical bureaus, the numerous land offices of the United States, are constantly active in correcting the geography of the interior of the country, producing a vast quantity of interesting maps, which increases daily in number and value.

That excellent institution, the Coast Survey, is bringing to light every year new and important facts respecting the nature of the coasts and of the surrounding American seas. In short, we may say, that not only is American discovery not ended, but that it is progressing at a more rapid rate than ever.

Accordingly, it is evident that while, on the one hand, our work becomes daily less easy to perform as regards the old materials, from their rapid destruction, growing scarcity, and increasing price, it also becomes, on the other hand, more difficult of execution with respect to the new materials, owing to their rapid increase and their enormous diversification.

The historical, as well as the physical sciences, are becoming extended and ramified in such a way, that it is easy to see that the time is fast approaching when it will be incomparably more difficult to master their results than it is at present. If we do this now, if we create a well organized institution for the reception and preservation of every new map along with the old ones, we shall then be prepared for every emergency; the subsequent discoveries, however numerous they may be, can easily be added to the acquired treasures.

Since the destruction and dispersion of the American chartographical collection of King Ferdinand at Seville, the concentrating of all American maps and historical and antiquarian documents into one focus is now, for the first time, made possible again. Now there exists again a government and nation, the interests of which are so intimately interwoven with all parts of the whole continent, that the name "Americans" has been given to them *par excellence*. The whole continent of America finds in the United States a central power nearly in as high a degree as formerly in Spain. In fact, the United States, the commerce of which enters every harbor, inlet, and river of the con-

tinent, derives already much more advantage from the whole of America than Spain when she received it from the hands of the Pope.

If the United States would not be found inclined to give life to the plan proposed here, then there would be left as little hope for its realization as Columbus would have had for the carrying out of his project had Ferdinand and Isabella refused him their assistance.

ON THE "PROGRESS OF ARCHITECTURE IN RELATION TO VENTILATION, WARMING, LIGHTING, FIRE-PROOFING, ACOUSTICS, AND THE GENERAL PRESERVATION OF HEALTH."

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FIRST LECTURE.

Professor Henry introduced Dr. Reid to the audience, and, in adverting to his plans for ventilation, quoted an extract from some recent proceedings of the Royal Institution in London, where Dr. Bence Jones had given certain statistical details showing the great reduction of mortality in an hospital which Dr. Reid had ventilated, and that the mortality increased again when the ventilation was suspended.

After responding to the remarks of Professor Henry, Dr. Reid claimed the indulgence of the audience in entering on a course while still imperfectly acquainted with this country, and perhaps not yet fully acclimated to it, as the experience of personal illness for the last fort-night had taught him.

Dr. Reid then commenced his first lecture with a general sketch of the position in which man is placed on this globe. With his natural wants at first supplied in a congenial climate, he was still, at a very early period of history, like a traveller without a guide in respect to many departments of *physique*, except those external senses which an omnipotent creator had given him wherewith to steer his course in the material world. Increase of knowledge, arts, and manufactures gradually accompanied an increasing population. New climates, new wants, and new occupations stimulated his ingenuity and rewarded his invention as much as it increased his comforts. Dwellings in caves or clefts of rocks, such as are described in the Sacred Scriptures, as well as tents and huts, the primitive abodes of man, soon gave way in many places to more systematic habitations, though these are still to be found away from the scenes of civilization. Monuments and public temples then arose in Cyclopean, Egyptian, Druidical, Indian, Chinese, and Mexican architecture. The Greeks, with the finest eye for beauty and proportion, excelled all their predecessors; the Romans added a gorgeousness and luxuriance of ornament that competed with, without rivalling, the severe and more scrupulous taste of Grecian architecture; and then followed a host of styles that have multiplied indefinitely, in

which the spire and the dome, the pointed and the circular arch are continued with endless modification, to the crystal palace and iron buildings of modern times.

But during all this period comparatively little attention was paid to the question of air, which has been so much the subject of later investigation. Buildings were at first too imperfect in their structure and fittings to form those air-tight receptacles that have multiplied so largely in our day. The same resources and machinery were not available for their construction. The habits and occupations of the people were different. Few read, and still fewer wrote, till the press began to diffuse its influence among mankind. The illumination of rooms at night with an artificial daylight by means of gas is but a recent invention.

But with all these inventions the duration of human life has not increased, except in local and special instances. Passing over the times of the ancient patriarchs, human life seems still, on the whole, to have been diminishing from the time when it is generally supposed to have been reduced to threescore and ten. How many places are there where from a quarter to a half of the population now die within from five to ten years; born, as it were, to pass through an infancy of suffering and sorrow, and then to disappear from this transitory scene. And then, if we look to adults, is it not true that many, so far from attaining threescore and ten, are cut off before they are twenty-five? An age of fifty years is beyond the average, and threescore and ten, or upwards, is still more rarely attained. But is there any just foundation for the belief that threescore and ten is the allotted period for man's existence? Is the passage from the Psalms correctly interpreted to which this alleged maxim is usually ascribed? He contended that it was not; that Biblical critics usually attributed this psalm to Moses, believing that it was written by him in the wilderness, when the Israelites were exposed to great suffering, and as yet he had met with no clergyman of any denomination who was disposed to insist on the popular interpretation usually ascribed to it. He thought the subject one of great practical importance; that the question should be set on a right footing; that if it were not only possible, but probable, that a marked extension of five, ten, fifteen, or five-and-twenty years could be given to human life by attention to the moral, religious, and physical elements that entered into it, nothing would contribute more to place the whole subject of the care of health, the increase of comfort, and the prevention of disease on a better footing. It would regulate, or at least affect, the period of infancy and education, the time of entering on business, and form an element in all subsequent concerns of life. Above all, it would be one of the strongest checks upon that system of fast living and that incessant strain upon the nervous system that was so marked in thousands and tens of thousands of cases, especially in populous cities, whether we looked to London or Paris, to New York or St. Petersburgh. Vain would the attempt be to extend the duration of man's life if the nervous system was exhausted, whether from an honorable ambition, an

imperious necessity, a corrupt luxury, or a want of faith, hope, and contentment in the providence of the Creator.

Dr. Reid then turned his discourse to the physical evils attendant on human life, and explained the magnitude of that resulting from defective ventilation. Man respired, on an average, twelve hundred times an hour during the whole period of his existence. The lungs contained millions of cells, and if pure air were not supplied all these provisions for life and health were more or less useless; the blood became changed in its qualities; the brain, the eye, the ear, and every tissue and fibre of the human frame were more or less affected. The result varied in every degree—from the most trifling headache, listlessness, or langor, to every variety of fever, scrofula, consumption, or even, in extreme cases, to sudden and immediate death.

In large cities and in all populous districts a proper system of drainage and external cleansing were the true remedy for periodical evils too often attributed to wrong causes. These being secured, the right ingress and egress of air in individual buildings and habitations became the next desideratum.

Few cities, comparatively, large or small, were cleaned to the extent necessary for the right preservation of health; nor was it to be expected that this subject would receive adequate attention till the united efforts of medical men, engineers, architects, and agriculturists should be brought to bear upon it. Great progress had been made, unquestionably, in recent years; but a more systematic, combined, and harmonious effort was desirable than was in operation, either in this country or in Europe, so far as I have had the opportunity of observing. The medical profession was responsible for pointing out the sources of disease and death, but, without the aid of the agriculturist, it was, in general, found impossible to obtain the funds necessary for effective cleansing; and what could be done in this respect where a good system of engineering did not afford an ample supply of water and the requisite drainage, or where a defective architecture did not provide the proper facilities for the removal of refuse? In London, after the experience of upwards of a thousand years, the authorities had at last become convinced that the condition which the river attains from the drainage thrown into it is an evil of the greatest magnitude, and a reference to the newspapers of the day would show the determination to reduce this evil, though nothing effectual can be done under an expenditure of millions of pounds. Is it not the case, that in this city the continued drainage into the canal may become more and more objectionable every succeeding year, and is there not abundant evidence that a right system of drainage and sewerage, with proper attention to the ventilation of drains, would here lessen disease and suffering? In Paris the whole atmosphere is sometimes tainted with an ammoniacal odor; and who has ever crossed the "Unter den Linden," in Berlin, at least when in the condition in which it was a few years ago, without being admonished of what had still to be done in that city. Modern chemistry has not yet developed and explained all the varieties of ma aria, natural and artificial, that interfere with the preservation of a pure atmosphere, but it has most emphatically pointed out many of their sources in innumerable habita-

tions in cities, villages and populous districts, as well as the means of correcting them. It was a self-evident proposition that the first step in all effective ventilation is to start with a good atmosphere; but such was the apathy, indifference, and sometimes the ignorance, on this point that it often became a most troublesome question to deal with in a satisfactory manner, particularly where tracts of ground had become saturated with debris in a perpetual state of putrefactive fermentation, or where streams or stagnant water were loaded with similar materials. In the great theatre of the globe itself, the general purity of the atmosphere was sustained by the mutual relations of the animal, the vegetable, and the mineral kingdom; by the perpetual rotatory currents flowing from the equator toward the poles and from the poles towards the equator; by that great peculiarity in all gases and vapors which constantly led to their diffusion through each other, however different in specific gravity, so that nowhere on the surface of the earth where there was free access to the external atmosphere could any accumulation of any noxious product take place without a process of dissipation and dilution being immediately commenced; and by the chemical action of the air, which was perpetually tending to oxidate or burn all malarious products. But how largely were these natural agencies counteracted, within as well as without doors, when there was a deficiency in the supply of air, or an excess in the material of decomposition. Many were the districts in which a rich and luxuriant vegetation consumed the products that gave rise previously to fever and ague. Travellers have expressed their great surprise at the total absence of these diseases under circumstances where they had anticipated their severe operation, and traced, subsequently, to the action of special plants the conservative influence that guarded them from danger. Let this lesson, said Dr. Reid, not be neglected; let it be applied in full force, and the facts be studied and developed with an untiring assiduity, till miasma shall be largely overcome in all cities subject to its influence, and the water-lilly and other aquatic plants shall have improved the condition of all accumulations of water in their vicinity, as much as an active and vigorous vegetation purifies the air that moves upon the land. If he dwelt more upon this point than might at first appear requisite, it was because its importance, though admitted, was by no means adequately estimated. He did not consider that there was any question connected with the material world that promised greater blessings to large cities and populous districts than those that would flow from professional investigation and practical experience in this department, combined with the information available from former ages, and the practice of different nations. It had been demonstrated that a large proportion of the deaths that filled the annual bills of mortality arose from preventible causes; and in making any estimate on this subject, it ought never to be forgotten that every death indicated many cases of disease and suffering that were never registered in the ordinary tables. How great, then, is the question at issue, and how many and how varied would the channels be through which its right solution would affect society?

Dr. Reid then showed by experiments the fundamental principles

of ventilation, illustrating the tendency of the air to assume rotatory movements, and thus induce the removal of vitiated and the supply of fresh air whenever expansion or any other cause produces a disturbance in the atmospheric balance. The effect of the human frame in inducing such currents was then pointed out. The body always ventilates itself if the natural currents it determines are not impeded by the architecture which surrounds it.

A special ventilating shaft has been constructed in this Institution for the illustrations, and a connexion is established between it and a tube and chamber in the experimental table, by which a ventilating power is brought to bear on any visible vapors used in explaining the principles and practice of ventilation.

SECOND LECTURE.

Dr. Reid commenced this lecture with different illustrations of the movement of air. Mechanical means—as pumps, fanners and bellows, or a current of air or water, the action of heat, the impulse of steam, and the repelling power of electricity—had all been employed with the view of moving air; and all these forces had been practically applied in sustaining ventilating operations, with the exception of electricity. This agent, hitherto, had only been used experimentally.

For all ordinary purposes, no power was so generally useful and available for ventilation as that arising from the action of heat on air or other gases. Referring to the ventilating shaft connected with the experimental table at which he lectured, it was shown that a column of heated air in the interior could not balance or resist the pressure of the colder air in the apartment from which it was supplied, air being admitted freely into it from the external atmosphere. It was not strictly accurate to say that heated air ascended, in describing this movement in a technical manner. It was more correct to state that air, when warmed, became expanded, and lost its power of balancing the contiguous air, which then pressed in upon it on every side and forced it upwards. The right understanding of this point was essential in the study of all the more familiar phenomena of ventilation. It was then shown, that on establishing a free communication with the lower portion of the heated shaft, a flexible tube could be made to carry a ventilating power in any direction, and, at the fixtures connected with the table, flame, smoke and various colored vapors were made to move upwards, downwards, laterally, and in other directions, according to the position in which the apparatus used at each was placed, and the amount of power brought to bear upon the materials employed.

The tendency of air, when falling in temperature, to descend to a lower level, was then pointed out. This was illustrated practically by the exhibition of a heavy, cloud-looking vapor, that was poured with facility from vessel to vessel and rolled along the table in a continuous stream, as if it had been an ordinary liquid. It was formed

by the action of nitric acid, mercury, and alcohol, and used frequently in giving indications of aerial movements that would otherwise have been invisible. Though the materials that became the principal object of attention in ventilating operations were of great tenuity, it was never to be forgotten that they might, in numerous respects, be treated in the same way as water and other liquids.

The quantity of air desirable for ventilation then came under consideration. For each respiration the actual amount required was small. From twenty to thirty cubic inches were sufficient for this purpose; but the expired air contaminates immediately a much larger amount of the surrounding atmosphere. At the same time the surface of the body is continually exhaling vitiated air in the same manner as the lungs. Further, almost all kinds of clothing soon become more or less charged with animal exhalations, and require some addition to the ordinary supply, particularly if dyed with certain chemicals and exposed where they may have imbibed moisture. It is also equally important to notice that every variety of temperature, electrical condition, and humidity in the atmosphere produces a corresponding influence on the sensations as affected by the amount of air brought in contact with the body in a given time. Further, not only are there great varieties of constitution in different individuals, but even in the same person. Before and after dinner or any other refreshment, before and after exercise, and under many other circumstances, very different quantities of air become agreeable or disagreeable, and refreshing or oppressive. Lastly, minute and variable portions of impurity from smoke and manufactories, or from terrestrial exhalations, often modify the amount of supply that is desirable for all constitutions.

It will not be surprising, accordingly, that there is perhaps nothing in respect to which there is a greater difference of practice than in the amount of air given for ventilation, even where we assume that its effect is not still further modified by its mode of introduction and discharge, and the efficiency with which it has the opportunity of acting in passing through the apartment to be ventilated.

It is surprising with how small a proportion of air existence can be maintained for a long period when the system is comparatively inactive. Dr. Reid then described an experiment, in which he had been hermetically inclosed in a case that was not broader than his shoulders, deeper than his chest, or longer than himself; and stated that he had continued there for upwards of an hour, the attendants being ordered to take him out whenever he ceased to answer questions or to give distinct replies. During the whole of that period he had not been particularly incommoded, after getting over a feeling of oppression that attended his first respirations. Apprehensive, however, of some subsequent injurious effects when the oppression he expected did not increase so rapidly as he had anticipated, he directed the case to be undone before any indications were given such as would have led his assistants to have anticipated this order. Nor did he suffer so much as he had expected from the effect subsequently, though headache and restlessness continued for some days to a degree that prevented him from renewing his observations to the extent he had desired.

This experiment was important in corroborating the fact that life might often be sustained for long periods, even in limited quantities of air, where animation was not temporarily suspended.

On the other hand, at different times and under other circumstances, he had suffered more from air not nearly so much contaminated as it was in this instance, and adverted particularly to the fact that the intensity of vitality was often very different in different individuals, and also in one and the same individual at different times. To impress this upon the attention of the audience, an experiment was then shown, in which a common candle, a wax candle, an oil lamp, a spirit lamp, and a gas lamp, were kindled at the same level under a large glass shade, all communication with the external atmosphere having been cut off. In a short time the air became so vitiated that the common candle ceased to burn. Subsequently the wax candle was extinguished, then the oil lamp; the spirit lamp came next in order, and last of all, but long after the others had ceased to burn, the gas lamp was also extinguished, struggling previously in the form of a long pale-blue flame. In the same manner death took place among different individuals, even from the very same causes, in very different periods of time, some sinking without a murmur where the bystanders scarcely noticed the causes that deprived them of life, while others sustained themselves throughout a long and painful struggle.

Dr. Reid then described the manner in which experiments on respiration had been made with small quantities of air, and the peculiarities of the apartments constructed at his lecture room at Edinburgh for researches on respiration and ventilation, where the amount of air supplied to numbers, varying from one to two hundred and fifty, could be precisely ascertained and controlled. Sometimes one or more individuals were placed in an air-tight box, containing a definite amount of air. On other occasions one hundred individuals or upwards were placed in an air-tight room with a porous floor and a porous ceiling, the cavities below and above communicating with channels by which air could be made to enter and be withdrawn in any required proportion.

From these experiments and others the conclusion was drawn that ten cubic feet per minute is an ample allowance of air for an adult—far more than he generally has in ordinary habitations, but not more than every ordinary structure should have the means of providing at a minimum. Dr. Reid was prepared to admit that a less amount would generally sustain health, but asserted that it would not give the comfort and maintain the constitution in such good condition as a larger allowance. In extreme atmospheres, loaded with moisture or charged with special impurities or malaria, and at comparatively elevated temperatures, there was no limit to the amount of increase that proved grateful to particular constitutions. He had, in some cases, given forty, fifty, and even a larger number of cubic feet per minute with advantage, but there the velocity of the air acted essentially as a cooling power from the great amount brought to affect the body in a given time. Such velocity was not desirable where an equivalent effect could be produced by cooling the air previously. But

in looking to this question as one that had to regulate practice in construction and the appliances used in connexion with ventilation, he was satisfied that ten cubic feet per minute for each person would be amply sufficient, wherever it was possible to control the temperature and the hygrometric condition of the air to be used.

The practice of merely determining the amount of cubic or superficial space to be given for each soldier in a barrack, each patient in a hospital, or every criminal in a prison, and leaving every other question or means of ventilation to accident, had never been satisfactory, and was now abandoned in all the best buildings for these and other purposes. No dependence whatever can be placed on such a provision beyond the actual amount of pure air they may contain before occupation. The true question is, to determine the amount of pure air that can be made to pass through wards, cells, or any other spaces in a given time, with a maximum of the ventilating power in action, valves or other arrangements reducing the effect to any desirable standard.

In cases with systematic ventilation properly applied, a man in a room densely crowded may have more air than one in a confined area with ten times as much space for his own occupation. Rooms in different habitations vary as much in the amount required at different times and seasons as many public buildings. Further, there is nothing more deceptive to those who have not studied the subject practically than the numbers of persons that can stand on a given space. In special trials, made with the view of determining the numbers that can be accommodated on a floor of known size, several cells were selected at the prisons at Perth, in Scotland, and able-bodied men (engaged at that time in completing the building of the works) were requested to stand in them as close as they conveniently could. Seventy were then counted in one cell having a floor of seventy-two feet, and ninety in another having a floor of ninety-two feet. He had repeatedly seen at the bar of the House of Peers, in London, and in many other places an individual standing upon each area of one foot. When the body of the late Duke of Wellington lay in state at Chelsea hospital, previous to the funeral, he had seen a more dense crowd than he had ever witnessed on any previous occasion. Many were literally crushed to death in this crowd, and numbers who escaped death had the appearance of persons who had fallen into a stream of water and been thoroughly drenched. The morning was cold, calm, and gloomy, such as would have suited the description many foreigners give of a London atmosphere at that period. There was no fog, however, though a small cloud of vapor hung heavily over the densest part of the crowd. It should be remembered, then, that in cases of great interest, all rooms, public and private, are liable, generally or locally, to have like numbers crowded into them, and it becomes, therefore, imperative on those who desire ventilation to state the number to be provided for, rather than the mere area of the floor.

In the chambers for Congress the floor space allotted for individual members was upwards of twice as much as that given at the Houses of Parliament in London, taking into consideration that occupied by

the benches or individual seats. This, however, was not an unmixed gain in the House of Representatives at Washington, since the large area of occupation necessarily increased the difficulty of hearing and of seeing the expressions of countenance during the progress of debate.

In explaining the estimate given of the amount of air desirable for ventilation, it was stated that a temperature of sixty-five to seventy would generally be found most acceptable, and a supply of moisture in the air, such as was indicated by a wet-bulb thermometer (the hygrometer in common use) when it showed a temperature five degrees below that of the ordinary thermometer.

The methods of determining the quality of the air in ventilated apartments then engaged attention. None was so pre-eminently available as that of going out of doors where the atmosphere was pure, and then comparing the effect there with that of the apartment under examination. Important as this mode was, it was not, however, sufficiently precise, nor could it always be put practically in operation with convenience while differences of temperature and a want of sensibility in the nostrils, or a loss of the sense of smell from cold, interfered with a correct decision. It was a matter of great practical importance, accordingly, that some accessible and convenient test should be available that would at all times and seasons give an indication that would tell the purity of the atmosphere.

For this purpose Dr. Reid had introduced an instrument called the carbonometer, which was then explained. It admits of a great variety of forms. That shown in action consisted of a bent glass tube attached to a phial containing water, a few drops of lime water being placed in the angle of the bent tube. On taking out the stopple from the phial a portion of the water slowly escaped. This caused a flow of air from the apartment under examination through the lime water, which becomes more or less turbid, according to the amount of carbonic acid in the air. But carbonic acid is invariably present in a very marked proportion in all ordinary atmospheres contaminated by respiration, the combustion of ordinary lamps or candles, or the escape of vitiated air from a fire flue. Any excess beyond that in the atmosphere renders the amount of lime water used slightly opalescent, milky, or turbid and chalky, according to the amount. Forty specimens of air were shown, contaminated with various amounts of carbonic acid. A syringe may be used instead of a phial of water to cause the movement of air, or a few drops of lime water may be poured into a phial containing air to be examined, making comparatime experiments with fresh air.

THIRD LECTURE.

This lecture was devoted to the warming, cooling, moistening, and drying of air, and the exclusion and correction of external vitiated air.

Great progress had been made in recent years in elucidating many of the properties of heat, in tracing its operation on different kinds

of matter, and in perfecting and economizing the apparatus by which it could be rendered available for the practical purposes of daily life. The intimate connexion that had been proved to exist between heat, light, electricity, magnetism, and chemical action, had opened up new sources of investigation; but much remained to be done; for we were as yet scarcely beyond the mere threshold of discovery. In one and the same experiment an acid might be employed in conjunction with water to disintegrate and separate one by one the primitive molecules of a mass of metal, developing heat by the chemical changes thus induced, discharging electricity, which could be conveyed through a proper conductor, producing light on making or breaking contact with the wires employed to manifest the electrical action, and imparting magnetic power to iron and other materials.

We were no longer restricted to the ordinary fire-place, and though nothing could rival its agreeable cheerfulness and general utility, steam and hot water apparatus had given facilities that were unknown in former days.

The common fire radiated in the room in which it was placed in the same manner as the sun shone upon the earth, and would probably always continue the favorite in ordinary apartments. It had a peculiar charm in the ever-varying features of its luminousness that no other invention had equalled. The grand desiderata in respect to it were the right adjustment of its position in respect to altitude above the floor, which should not exceed from six to ten inches; the introduction of no more iron than was absolutely necessary for supporting the fuel below and in front; the size of the chimney, which was generally, till lately, four or more times larger than was requisite or desirable, wasting a great amount of air, and ventilating at a wrong level, unless special provision was made to counteract this defect. Many experiments were then described that had been made in reference to fire-places and flues, and one illustration minutely explained, where a flue nine inches square, and about twenty feet high, had worked four ordinary fire-places. These were afterwards closed above and in front, so as to be converted into furnaces, and, when in full operation with the same flue, each was found capable of melting iron with facility and rapidity. A register or valve was preferred near the top of the smoke flue, or, at least, at a considerable elevation above the fire. A special experimental illustration was then given of a circular fire-place, three feet in diameter, the red-hot fuel being visible and accessible all around it, and the products of combustion, accompanied by a blue flame, descending in the form of a circular wreath in the centre of the fire, and traversing the floor below, which was well warmed before they escaped into the chimney.

In England, though the open fire was usually accompanied by the production of smoke from the bituminous coal in common use, considerable progress had been made in the introduction of smokeless fuel during the last twenty years. In many buildings, soft coke or anthracite was employed, and Dr. Arnott had recommended a fire-place in which the fuel was kindled at the top in the same manner as a candle, all the smoke being consumed when the proper coal was em-

ployed, and sufficient attention paid to the construction and management of the grate.

In explaining the peculiarities of stoves, Dr. Reid insisted strongly on the excellence of those long used in the north of Europe, that were of considerable size, and had a pure porcellaneous surface. They were much larger than the iron stoves usually employed in this country and in England, extent of surface compensating for the want of intensity of heat, and the atmosphere they afforded being more grateful to the lungs and nostrils. Much ingenuity and skill were undoubtedly displayed in many of the stoves made in this country and the accompanying drums, but, as a general rule, the great majority he had seen were, when placed in the lower part of any building for general purposes, usually provided with pipes or channels for the ingress and egress of air that were far too small. They gave accordingly a sharp current at a high temperature rather than a large volume of a mild atmosphere. They were also generally without the means of supplying themselves with air from the house itself, instead of from the external atmosphere, an object of great practical importance in heating halls, passages, and public buildings previous to any occupation, or where a small amount of ventilation was sufficient.

Steam apparatus was then adverted to, the use of which Dr. Reid considered could be largely extended with advantages to individual habitations, even where the power of using a common fire was secured in the usual manner. It could be made to assume any desirable form. The principal difficulty in ordinary habitations was the boiler within doors. Great improvements had been made in modern boilers, so as to reduce largely any risk of accident, but the improvement considered most desirable was, that in which one boiler should be provided for a number of houses, and built in connexion with facilities for water baths, washing, &c., and from which steam for heating or culinary purposes could be supplied to each individual habitation in the same manner as gas, by special pipes. Steam, or steam power, could be rented in many places for manufacturing purposes, and there was no reason why similar facilities should not be extended to ordinary habitations in cities and villages.

Steam could be made to afford any required temperature, according to the form of apparatus used. With extended metallic rings, plates, or projections from the surface of a steam pipe maintained at 212°, a much lower temperature could be secured, corresponding with the amount of material in connexion with the pipe, and this form of apparatus, or hollow metallic cases with a limited supply of steam, necessarily gave a milder temperature. He did not consider a temperature of 212° objectionable when the air was pure, though he preferred a milder warmth; but higher temperatures, arising from the use of high-pressure steam, he had often seen attended with disadvantageous results, increasing with the elevation of the temperature sustained.

The action of the hot-water apparatus was then explained and illustrated by a glass model, in which colored water was thrown into currents by the action of heat, the warm water giving off caloric whereever it was desired, and then returning to the source of heat for a

fresh supply. This heating apparatus was preferred to the high temperature stove and the steam pipe wherever a mild and continuous heat was desirable, and where it was not required to carry the pipes or apparatus containing the water to a very high level, the strain upon the joints of the apparatus being in proportion to the altitude of the column of water they contained. The water could be maintained continuously at any required temperature under 212°. Gas stoves had been introduced in many places with advantage where a small chamber was to be heated, and where there was no convenience for any other arrangement. A most pernicious practice was, however, prevalent where they were used, the products of combustion being permitted to mingle with the air of respiration in apartments not provided with ventilation. Thousands upon thousands suffered annually where gas lights or stoves not ventilated formed the only source of warmth.

Dr. Reid then pointed out the comparatively ineffective results that arose from the action of heating apparatus that conveyed warm air too quickly to the ceiling of the rooms instead of distributing its power on or near the floor. Railroad cars frequently presented a temperature above 212° at the ceiling, while on the floor the thermometer might be down to the freezing point. They gave an extreme illustration of numerous buildings where the introduction of arrangements for securing the full action of warm air at a lower level would add equally to comfort and to economy. The peculiarities of external warmth arising from the rays of the sun were then contrasted with that developed by artificial means. Saussure made an experiment in which air had been raised to a temperature of 210° by merely exposing a cork case with glass cover to the direct rays of the sun, and preventing the cooling influence of the circumambient air. The rays of the sun did not directly warm the air, but the ground, from which heat was transmitted to the air resting upon it. In the torrid zone it would probably be practicable, even without the use of lenses or reflectors, to develop heat sufficient to produce a limited amount of steam. A patent had lately been taken out for concentrating the rays of the sun upon boilers in such climates. The great practical lesson which all these points taught was that we should endeavor to warm the lower stratum of air effectually in individual buildings. If this primary point be secured, the upper portion will soon acquire the necessary temperature from the natural ascent of warm air.

The cooling of air was in some countries, and at particular seasons, as important a question as the warming of air in temperate and cold climates. In India habitations were sometimes built under ground, the family occupying a lower and lower flat or series of apartments as the external heat increased. The construction of buildings so as to take full advantage of the shade, and of the basement in making channels of supply, was seldom made a sufficient object of attention. The production of cold by the evaporation of water was largely introduced in many places with advantage; but where the air was highly charged with moisture this method was disadvantageous, tending to saturate it to an extent that interfered with the natural exhalation and evaporation from the surface of the lungs and of the body. By

taking in air through apertures in turrets, or even by apertures elevated as much as was found practicable in different buildings above the level of the ground, great relief was often given. The warmest atmosphere in sunshine was generally at the surface of the ground, where no peculiar current or other special cause gave it a different position. In all cases where a ventilating power was available, the simplest method of producing a cooling effect upon the body consisted in inducing a current. A draught or current was agreeable or disagreeable, dangerous or salutary, in proportion as it was adapted to existing circumstances. The fan in a lady's hand and the punkah, or large fan used in India, were very different from the ventilating shaft or other instrument used to act on hundreds or thousands at the same time; they differed essentially in this, that while the former merely agitated the same air again and again, changing that portion in direct contact with the face or the whole of the body, the latter, in producing a similar effect, entirely changed the atmosphere charged with products of respiration or exhalation.

The use of ice, however effectual in cooling air, was generally too expensive. Underground channels cooled by a stream of water, removed or stopped when too much moisture was communicated to the air, were the most valuable and available means of reducing temperature; and where hot-water apparatus was provided for winter use, it might often be used as a cooling apparatus in summer by running a stream of cold water through it. The artificial evaporation of ether and water in rams could be also rendered useful in the production of cold, but no such apparatus had as yet come into general use, though perfectly successful in special experiments.

Moistening air was a comparatively simple matter, though often neglected. Very pure water should be selected for this purpose, and the evaporation should not be permitted under any circumstances where the water was apt to be decomposed. A porcelaneous or marble surface was preferred for evaporation. Iron was to be avoided, and steam from ordinary boilers, contaminated by oil or gases from corroded metals, was not to be used. Special copper boilers, set apart exclusively for this purpose, and block tin tubes, for the conveyance of the steam, were preferred in large buildings, where an atmosphere had to be provided for thousands at the same period. The steam prepared in this manner was also used to assist the heating apparatus. Whenever a thermometer with a bulb moistened with water indicated a difference of not more than five degrees lower than the ordinary thermometer, the addition of any further increase of moisture should be arrested.

Drying air is an operation for which no satisfactory process has yet been pointed out sufficiently economical to admit of its general practical application when air is warm and largely charged or saturated with moisture. When the temperature is lower, and the application of a slight elevation of temperature is not objectionable, the increased solvent power which the air thus acquires gives it practically a drying effect. In the sick chamber, in new buildings where the plaster was not dry, and in all limited or confined atmospheres where it was important to remove moisture, nothing was more effectual than newly

prepared lime. Dr. Reid had used this largely in many buildings occupied soon after completion, distributing, in one case, cart loads of quicklime in the air channels and in the different apartments where the pressure of public business induced the authorities to occupy courts of law the day after very extensive alterations had been completed, without waiting either for the drying of the plaster in the usual manner, or for painting and decorations. When a building was surrounded with an external malarious atmosphere, by a right system of drainage this could in general be removed, at least from the immediate vicinity. Where the drainage was not sufficient, an active system of vegetation became the next resource. If temporary or other causes prevented this being carried to a proper extent, the antiseptic power of caustic lime could be applied with great success. He was prepared to point out many opportunities where this agent ought to be used in all cities he had hitherto examined. Numerous other chemicals could be rendered available, particularly choride of lime, muriate of zinc, and other substances. Their effects were seldom, however, obtained to the extent they were capable of producing, from a want of knowledge on the part of those who applied them of the chemical details essential to their full operation. Where vitiated emanations were traced within a building to any special drain, close chamber, room, or other space, either in the basement or elsewhere, a special ventilating power should be brought to bear on them in the same manner as the ventilating shaft exhibited had been brought to act upon all the materials used in the illustrations given at the experimental table, unless the cause was altogether temporary and easily removed.

FOURTH LECTURE.

The ventilation of individual rooms and habitations formed the most important question connected with sanitary improvements. These were the places where the great mass of mankind spent the larger portion of their time; where they were born and where they died; there they generally spent the period of their infancy and childhood, wheir days of suffering and sickness, and recruited their daily strength with food and by reposing from their labors. A vitiated atmosphere at home corrupted the condition of the blood more than any other cause, inasmuch as it had a more continuous power of operation. The effect of each individual inspiration might indeed be trifling, but when repeated twelve hundred times an hour for days, and months, and years, and brought in direct action upon the blood itself in the lungs, it was to be expected that it should soon affect every fibre of the living frame.

In studying the ventilation of individual rooms and habitations, it was recommended that the rotatory movements of air in a confined atmosphere should be examined when an inequality of temperature was induced, and that these movements should be rendered palpable by chemicals producing heat and smoke. Franklin had made use of this expedient, and had it been more generally attended to, ventilation would have made much more progress than it had done. Experi-

mental illustrations were then given of these rotatory movements. In the external atmosphere the general ventilation of the globe depended on such movement. In the smallest space that man could examine they could likewise be traced. A peculiar argand lamp was then shown, in which hundreds of circular rings appeared when the air and gas were permitted to enter in special proportions. They afforded an example of minute rotatory currents indicated by the movement infinitesimally small particles of incandescent carbon. The audience were invited to examine these individually at the end of the lecture, as they could not be seen at a distance. Bearing in mind the fact that the living body, unconsciously to the individual, ventilates itself when this operation is not opposed by an air-tight or ill constructed apartment, an aperture for the ingress and egress of air in a proper position, and of the right dimensions, is the great desideratum. While a window serves this purpose, and a porous curtain diffuses the entering and out going air, it has taken a long time to carry conviction of the importance of additional resources in the comparatively air-tight structures of modern times, charged with products of combustion from gas and respiration, as well as other varying impurities. But when it is recollected that a thousand different circumstances arising from the peculiar position, form, structure, arrangement, furniture, and occupation of rooms, as well as their aspect in relation to the sun, prevailing winds, local influences acting on the air, the position of doors and windows, constitutional peculiarities, and many other details that might be enumerated, in addition to the changes of the season, the time of day or night, and the number of persons present, all contribute to modify the effect required, it will be obvious that the window alone is not sufficient for every ordinary apartment.

The great desiderata, in addition to the window, at least in rooms subject to a great variety of occupation, are the following:

1. A special flue, from the highest portion of the room, for the discharge of vitiated air.

2. A special aperture for the ingress of a warmer or colder atmosphere, when the external temperature, dust, noise, or any other cause, renders a supply by the windows objectionable.

3. The means of extending the diffusion of the entering air so that it shall not impinge offensively on any individual.

4. The means of applying a force or power to the ventilating flue, (heat is the most available for all ordinary purposes,) which shall increase the discharge to any required extent, and cause fresh air to enter by any channel provided for this purpose.

5. The exclusion of all vitiated air from the basement of the building, or any other source, either by the action of a ventilating flue or other equivalent measures.

These objects can, in general, be attained with facility and economy in building a new structure, without interfering with the usual details of construction to any objectionable extent. It forms a most important addition when the passages and staircases can be converted into means for the general supply and discharge of vitiated air, warming the air by an apparatus placed there at the lowest available level, and introducing a large internal window above every door communi-

cating between the passage or staircase and individual rooms. These, when open or shut to the required degree, allow the air in the passages and staircase to be used as a milder climate, whether in the heat of summer or the severity of winter—a perpetual ingress of fresh air and discharge of vitiated air being constantly maintained in the hall, passages, or staircase.

Dr. Reid then adverted to some models and to a series of diagrams, with which he illustrated, practically, the various methods adopted in experimenting on the subject, and in the construction of apartments where ventilation was introduced under very different circumstances, from which we select the following examples:

1. In this case, the ventilating aperture was immediately below the ceiling and above the window. A valve regulated the amount of opening. The air entering or escaping by this aperture must pass through a plate of perforated zinc about one foot deep, and extending the whole breadth of the window. Area of aperture through the wall nine inches square.

2. A room having a ceiling universally porous, the air entering between it and an air-tight roof, and two apertures communicating with this cavity and the external air which descends from one part of the ceiling and escapes at another.

3. A room where the fresh air is supplied from the whole surface of the wall in which the chimney is placed, excluding those portions below the level of the fire-place; vitiated air escapes by a special flue contiguous to the chimney.

4. A room in which, when crowded, fresh air can be admitted freely through a porous door from a prepared atmosphere in the passage, vitiated air being permitted to escape by a large panel or window above the same door.

5. A house having a special ventilating shaft capable of acting on all or any of the individual rooms, and of having its power increased, when necessary, by the action of heat.

6. A house in which all the vitiated air-flues are led into one large flue descending to the basement, passing then laterally into an adjoining shaft, whose altitude (from the basement to the roof) gives it great additional power when the fire is kindled at the lower extremity.

7. A house in which fresh air is supplied to the passage, stairs, and principal apartments, from a special turret on the shaded side of the house, while a discharging shaft, as in No. 6, commands the escape of vitiated air.

8. A house in which the heating apparatus (hot water) is so arranged as to present a warm surface on the floor of the staircase and principal apartments. Similar arrangements can be made with steam apparatus.

9. A series of habitations supplied from a general source with a ventilating power, and a steam tube in every house, and in every room of each house, where it is desired, in the same manner as houses are supplied at present with water and gas from one common source.

10. A series of diagrams, showing the imperfections of ventilated

apartments, under different circumstances, when not constructed with the resources explained.

In all these examples, whether apertures alone were made in humble apartments, or an extensive series of arrangements in first-class habitations, nothing was done incompatible with the free use of an ordinary window, or the action of a stove or open fire-place. The only peculiarity that required attention was, that there should be an ample supply of air in proportion to the demands made upon it. There was then no conflicting action between fire flues and the ventilating flues.

It was strongly recommended that the shaft or flue for the escape of vitiated air should always be constructed so that external wind should have no effect in producing a back current. No external top is better for this purpose than that recommended by a committee of the American Academy of Sciences at Boston. It differed from the cone in common use in this country, in having an addition above the top of this cone which expanded the aperture slightly above the line of the ordinary discharge. The ordinary form of cone of Mr. Emerson had the advantage of being more simple, though not so powerful in producing a draught. It ought to be recollected, however, that such terminations to ventilating shafts or flues were principally important in counteracting the influence of wind. They had no power in a calm. If heated by the sun, they would promote ventilation; if cooled by the state of the atmosphere below the temperature within doors, they would retard ventilation.

Dr. Reid concluded this lecture by a brief exposition of the condition of the habitations of the people in different cities in Europe, and illustrated by a drawing the numbers often crowded on a given space in many of the humbler dwellings, and houses of refuge for the destitute.

Bad ventilation was by no means confined to the abodes of the poor. None suffered more at times from this cause than the opulent in palatial edifices where extreme illumination and air-tight construction prevailed, though their wealth gave them great advantage in other respects. But great improvements had been made in all classes of habitations within the last twenty years, however defective individual examples might be. It was in vain, however, to insist on ventilation where there was a deficient supply of warmth and food. The general condition and health of the people was greatly influenced by the air they breathed, and this, in the course of time, affected the appetite; then the health gave way rapidly from the combined influence of bad air and want of nourishment. The low tone of the constitution induced a craving for unwholesome stimuli which affected the system still more powerfully. In one house inspected, near St. Paul's cathedral, in London, one hundred and twenty-three persons were found crowded in a few rooms; and in another, thirty or forty people were occasionally found in a single room. So great was the crowding of the poor in many of the most populous cities, that the question had been publicly taken up, and model lodging houses introduced, which, with the supervision of licensed lodgings, promised to be of inestimable value in improving the condition of the humblest portion of the population. He found that model houses had also been

constructed in different cities in this country, some of which he had inspected with much interest. He did not know many questions connected with the material well-being of man more important than that of improving the condition of the dwellings of the people. It was every day becoming more and more a moral, a religious, and a political, as well as a physical question. Many were driven to the very extremes of socialism in its most repugnant forms as often from the want of proper habitations as from any other cause. If the family system and the home circle were essential to the foundation of a nation's prosperity and happiness, then too much importance could not be attached to the improvement of the habitations of the people. Wherever the laws, the institutions, the state of morals and religion, and the resources of a country led to their being carefully made, the effects were manifest in the external aspect of the people, to say nothing of the many other blessings that flowed from this source. But let them look to the other picture, and there it would be seen that if this object were neglected, whether from defective legislation, imperfect adaptation, or careless and indifferent landlords and proprietors, vice and intemperance were certain to mark the results. It was by no means desired to attach an exclusive importance to this question of the habitations of the people. It was only one of many causes that contributed to their elevation and comfort, or to their misery and degradation. But viewing this matter in a practical manner, it was obvious that the greater the degree to which science perfected and economized the means of combination and improvement, sustaining at the same time all the peculiarities and associations of individual families, the greater would be its success in promoting the best interests of the people.

Dr. Reid then adverted to the general appearance of the population in different European countries, and remarked that he had nowhere seen such marked specimens of sturdy and robust health and comfort as the Swedish guard, at Stockholm, presented when he visited that city. The soldiers were not tall, but they had a firmness, density, and compactness of limb and muscle which he had never before witnessed in any body of troops; while their countenances evinced a composure, along with an entire absence from care, dissipation, or fatigue, that manifested at a glance the high condition of their health. It would be important if in every city there was at least one trained band of men who could be seen from time to time, and give an example of the appearance that human nature ought to present amidst the mass of inferior constitutions that appear in cities, whether arising from bad air or any other cause.

FIFTH LECTURE.

On this occasion, Dr. Reid commenced with a reference to his preceding lecture on individual rooms and habitations, and called the attention of the audience to numerous cases that had come under his notice, both in this country and in Europe, where a great amount of

vitiated air prevailed in the upper portion of different buildings. There vitiated air was prone to ascend by passages and staircases from other apartments, and if the roof or ceiling of the attics had no adequate discharge, the moisture of respiration was condensed during the cool of the night, though the warmth of the sun gave an elevated temperature to this space during the day. He had seen numerous houses where dry rot from vitiated air had entirely destroyed floors in the attics, while the lower floors were comparatively sound. In public buildings the same tendency was equally manifested under parellel circumstances. An example was cited of a church in Scotland, near Edinburgh, where the upper part of a long ladder was found so completely decayed that it was broken with facility by the hand, while the wood of the lower portion was perfectly sound. This church had been ventilated apparently by apertures in the ceiling, but there was no discharge above in the roof, so that they were totally useless, except in so far as they permitted the air in the roof to add its volume to that below; but at night the moisture of respiration condensing on the timbers of the roof, which were finally entirely destroyed by the dry rot. In London a very marked case occurred in the new post office, where, a few years after it had been occupied, large quantities of a brown fungus were found in the roof extending in branches sometimes ten, twelve, or sixteen inches long, and as thick as a man's finger. The products of respiration and of the gas lamps below had formed the food that supported the growth of the fungus.

The ventilation of public buildings was the next subject of consideration. The same principles were applicable there as in the ventilation of individual habitations; but the numbers crowded in a given space, the fixed position and comparative restraint that necessarily accompanied many of the duties of official life, the long sittings of a judge in court, of a member of the legislature, according to the public business transacted, the ever-varying numbers present, and the changes of the external atmosphere during long protracted investigations and debates—all conspired to render a degree of control and power of ventilation requisite that was not needed in ordinary apartments. Further, in public buildings, large halls, corridors, and passages were often necessary, besides numerous individual apartments applied to very various purposes, and subsidiary to the principal assembly rooms for the transaction of public business. These varying in number from one or two to hundreds, and sometimes covering several acres of ground, in many cases required to be ventilated in unison with the principal assembly rooms; and without the adoption of some general system for the whole, the warming and ventilating would be equally defective and incongruous with the architectural character of the building were the different portions of it erected without reference to any general plan.

The first point to determine, in the construction of a large building, in reference to warming and ventilating, was the number of apartments, halls, and passages that were to be used in such a manner, or so arranged that they must be subject to one system of ventilation to maintain uniformity of action. Then came the determination of the question, how far it was necessary or desirable to unite the varied

groups of apartments and of individual rooms that required the power of independent action in a more comprehensive scheme, that would economize and facilitate the whole operation, without sacrificing the special requirements of each separate control?

These preliminaries being settled, the next step was to determine whether a ventilating shaft, put in action by heat, should be resorted to for the necessary power, or a mechanical instrument sustained by a steam engine or any equivalent force.

Where offices occupied by a few individuals only were to be ventilated, and where they were only required for very brief periods, neither large shafts nor machinery might be requisite, if proper apertures for the ingress and egress of air were arranged, as in well-ventilated individual habitations, with small ventilating shafts or flues.

A shaft being made to operate on the vitiated air to be discharged, tended, more or less, to produce a comparative vacuum in the apartment to be ventilated, and hence the origin of the term *Vacuum ventilation.*

An instrument moved by mechanical power, and acting directly in expelling vitiated air, produced a similar effect. But when it was made to ventilate by blowing in fresh air, it tended to create an excess of pressure within the apartment it ventilated; air then escaped outwardly by open doors and windows, as well as by any appointed channels, if they were not extremely large. This was termed *Plenum ventilation.*

In the most perfect form of ventilation, the ingress and egress of air were so nearly balanced that there was little or no tendency to the air being drawn inwards or pressed outwards at doors or other apertures not provided for its regular ingress or egress. The less the tendency to either plenum or vacuum ventilation the better. And even where shafts alone, or instruments alone, were used, it was always desirable to reduce the tendency to a plenum or vacuum as much as possible by the right adjustment of supply and discharge. In law courts, theatres, or assembly rooms of great complexity, and having numerous entrances to galleries, to seats on the floor, and to special places allotted for particular purposes, and still more if they were subject to great fluctuations of attendance, a plenum and vacuum power was combined where the greatest perfection of effect was desired.

Having determined on the leading arrangements for the supply and discharge of air, the amount to be given per minute, the apparatus required for heating, cooling and moistening, and any of those endless varieties of contingencies which each individual building might require, whether from the purposes to which it was to be applied, the locality in which it was to be placed, or the climate to which it was subject,—the details of the supply and discharge, the position of valves, and the precise arrangements required for the ingress and egress of air, should then be planned. This, in general, will be found to require much more attention than was formerly given to such questions. It is the rock of difficulties in all disputes where separate authorities are responsible for decoration and structure, and for the comfortable and effective result of ventilation. If the architect do not profess ventilation, or the authorities do not confide that department to him, it will be obvious that if no right mutual understanding be

amicably and accurately carried out, then an *imperium in imperio* will interfere at every step. If the architect have supreme power, then he must necessarily become responsible for the ventilation, particularly if he controls and determines the apertures for ingress and egress, and the amount of diffusion given to the entering air. The ventilator cannot be responsible for his plans if he disapproves of alterations which the architect may carry into effect. Again, if the ventilator shall have the directing authority, the architect may say that he will not be responsible for the appearance of decorations and their general effect if they are adapted for ventilation in a manner of which he does not approve. It will be obvious, then, that until schools or colleges of architecture shall give the future student the opportunity of applying himself to this subject as much as its importance demands, we must consider this branch in a state of transition. When the architect does not profess to attend to ventilation, it cannot receive from him that full assistance and development which could otherwise be given in the original design, and in harmonizing all the conflicting claims of the different departments of the profession.

Dr. Reid then gave experimental illustrations of the action of ventilating shafts worked by heat, of steam ejected from a small glass boiler, and of different classes of instruments for the movement of air, pointing out more particularly the difference between the air-pump, the screw, and the fanner. In speaking of instruments alone, he gave a decided preference to the two latter, from the simplicity, continuity, and equality of their action; though, in particular cases, where air at a higher pressure than usual was necessary, he preferred the air-pump.

At the same time, wherever a ventilating power was essential, and the difficulties to contend with were not great, he recommended the shaft as abundantly sufficient for all ordinary purposes; stating that any common laborer could be taught to attend to it, and that it merely required to have a proper supply of fuel from time to time; whereas, with an instrument worked with an engine the constant attendance of an engineer was essential. That was the result of his experience. He had been the first, so far as he was aware, to introduce large fanners, worked by steam engines, fitted up expressly for ventilating buildings, and still recommended their use as much as before, under similar circumstances; but he could point out places where they were not necessary, and where the substitution of a shaft would effect a considerable annual saving.

In respect to the course which the air should take in passing through any apartment to be ventilated, much should depend on the special difficulties to be overcome in each individual case. The ascending movement was preferred for all ordinary purposes. He had used that movement more extensively in public buildings than any other, though in old buildings, where it had to be applied under great limitations, there were often many difficulties to be met. Among these the most formidable in general was the want of sufficient diffusion for the entering air. In the late House of Commons, which was made the basis of experiment for determining the accuracy of his views and the test of their application to the new houses of Parliament, he had

been led to the conclusion that the restrictions which the state of the walls and the time for applying his plans in this building necessarily imposed on him, universal diffusion through a porous floor was the only scheme of supply that met the realities of the case. This arrangement for the supply he introduced accordingly; and, for fifteen successive years, after which the building was pulled down in consequence of the progres of the new works, the government and the House uniformly supported it, notwithstanding some obvious disadvantages that were met by peculiarities of details. The House of Peers, also, after it had been sustained for three successive years, requested that similar arrangements should be introduced into their chamber; but the means allowed for this purpose did not permit the views to be applied as completely as in the House of Commons—the progress of the new works leading the authorities to expect that they would soon be enabled to occupy the new House of Peers.

Tables were then presented, showing the observations that had been made every hour during the sittings of the House of Commons for fifteen successive years. Large diagrams were also shown explanatory of all the peculiarities of the arrangements adopted in the late House of Commons, and of the experimental buildings previously constructed by the Lecturer at ldinburgh in reference to the ventilation. In the temporary House of Peers arrangements were made that enabled a large movement to be tested whenever the weather gave a suitable temperature, according to which fresh air was permitted to descend from one part of the ceiling and ascend to another. This was independent of the usual arrangements adopted there. A similar movement had also been in use in his lecture-room at Edinburgh from the time it was constructed in 1833; but there he did as he pleased, and gave a supply and discharge by a large aperture having an area of several hundred superficial feet. The wall of one side was left out in reality, so that air descending from the contiguous apartment moved in one broad current to the class-room. A movement of supply and discharge by the ceiling requires a very large amount of apertures, otherwise much of the air passes from the aperture of supply to the aperture of discharge without doing any good to the ventilation of the lower part of the room, where alone it is essential to have fresh air. Again, there are cases where a direct descent is preferable to all other movements. These occur principally where there are peculiar difficulties connected with the supply and the condition of the floor. At one period he (Dr. Reid) was under the impression that such a movement might have been the best for the old House of Commons; but, on investigating the circumstances that led to this view, it was found that the whole arrangements for the ventilation had been improperly changed and neglected during his absence, and, with the sanction of the government and the members of the House of Commons who attended the investigation, everything was restored to its former position.

Descending ventilation could be rendered perfectly successful even in a crowded assembly, but never without a much larger supply than was requisite with an ascending movement. He had made the experiment repeatedly with individuals, and in a room specially constructed

for testing this and other questions connected with architecture, and the result was invariably the same. Descending ventilation was also inapplicable where lights were introduced that were not specially ventilated. Where the products of gas and oil lamps were added to the products of respiration the amount of ventilation requisite was so large as to preclude a proper supply without a movement of air so great as to be objectionable on this ground alone, and, at the same time, very expensive.

In some experiments, in which a number of the members of the Royal Society of Edinburgh took a part, one of the clubs formed of members of the society dined in one of the experimental rooms he had constructed. Fifty attended on this occasion, including the president, Sir Thomas Brisbane, the late Lord Cockburn, and other gentlemen connected with literature and science. The hotel-keeper at whose establishment the club were in the habit of dining was well acquainted with the habits of those who were present, and stated next day, when he presented the bill, how much he was surprised at the amount of wine taken on this occasion. This, at least, was the point that principally attracted his attention. After providing rather more than a good average supply, he had to send a carriage for more, and again, as the evening advanced, he had to send a second time for further supplies. The dining room at his hotel was not then, at least, ventilated, and gas and vitiated air from respiration soon satisfied the appetite. But in a room supplied with a large and flowing stream of air, the natural powers of the constitution were not subdued, and, what is curious, none of those present were at all aware that they had taken anything unusual till they were informed of it next day. Many is the unrefreshing meal and subdued appetite that destroys the strength of the constitution in apartments loaded with the vapor of respiration and exhalation. Travellers, and, indeed, all persons, should be charged only half fare when they partake of refreshments in an ill-ventilated apartment.

If one wishes to see and study the practical importance of this question, let him go to ill-ventilated boarding-houses, schools, milineries, manufactories, and refreshment rooms, particularly in the crowded localities of large cities, and he will there trace one of the causes of impaired health which affects great numbers of the population. So thoroughly is this now understood in many places, that cases have been cited where workmen have struck for more wages in newly ventilated manufactories; the proprietors not perceiving that they could, in general, obtain an equivalent value from the exertions of those who were in better health and strength than the ventilation previously permitted.

Diagrams were then pointed out illustrative of the general mode of dealing with the ventilation of large buildings, special reference being made to the houses of Parliament, in London, and to St. George's Hall, at Liverpool.

SIXTH LECTURE.

In this lecture details were given as to the arrangements made at the late House of Commons, and contrasted with the provisions founded on them that had been executed for the application of his plans in the new houses. It was only right, however, that he should tell the audience that they were not completed under his directions; and that his plans there met with so many obstacles from alterations, to which he objected, that, in the year 1845, he considered it his duty to call the attention of the government to them, and to the necessity of an investigation. It being evident that he could no longer be responsible for the result, or for the cost, unless sustained in the arrangements authorized by the government and Parliament at the time his plans were adopted. He continued that it would be altogether out of place in so brief a course, to detain the audience with any minute statement of his own, or of others, on such a subject; but it would be equally obvious that he could not pass over this subject without some notice of the principal incidents that had occurred in so great a work, and he would, therefore, only give a very general outline of the case, and place in the hands of the secretary of this institution a copy of the evidence he was finally called upon to give openly and publicly at the bar of the House of Commons in respect to it, after demanding this or some equivalent opportunity in vain during the six preceding years.

The investigation he asked for was instituted in 1845, and in the following year a committee of the House of Commons took up the question. The committee included members of all political parties; the late Sir Robert Inglis was chairman, and Lord Palmerston and Lord John Russell were both members. After due investigation the committee passed resolutions that were in every respect satisfactory to him, and they also renewed, as a committee, their expressions of opinion as to the satisfaction given by the plans in the house they then occupied. But in the meantime new proceedings were instituted in the House of Peers, and after this renewed investigation by new referees, and by a committee of which the Marquis of Clanricarde was chairman, in a manner that did not permit, as Dr. Reid had then stated publicly in official documents, a proper investigation; a resolution was carried in the one house of Parliament, the House of Peers, that virtually negatived the resolution unanimously adopted previously by the committee of the House of Commons, and gave an authority to the architect over the ventilation to which he, Dr. Reid, could not assent. From the day this was officially communicated to him by the government he never once acted at the new houses, except under protest, though he gave such advice as the government still required from him, till he succeeded in being called to the bar of the House of Commons. But in the meantime the mayor and corporation at Liverpool had adopted, in the year 1841, the same year in which his plans had been adopted for the new houses, parallel plans for their great building, St. George's Hall, and the new assize courts. In 1846 the Liverpool committee inquired into the disputes at Parliament, and coinciding with the views of the House of Commons, and

not with those of the House of Peers, continued the support they had all along accorded, and, in 1855, when the whole works were completed, declared their satisfaction with the result. A committee of the House of Commons also had previously reported their success. Further, in an arbitration, in 1853, when a new investigation took place that lasted for thirty days, the arbiters sustained him in every legal privilege and award connected with his case, of which, at the new houses of Parliament, an attempt had been made to deprive him, founded on the evidence of the architect, with whom he differed.

If any one should think that even with this brief statement he had dwelt too much on this subject, he requested them to remember that he could not say less without appearing to evade a case that had led more to the study and progress of ventilation than any other with which he was acquainted; which had materially assisted in supporting the views he had previously expressed, and explained in his Illustrations of Ventilation, published by Messrs. Longman, of London, as to the right method of proceeding with the study of architecture and ventilation for the future, as well as to the mode of meeting the difficulties attending a state of transition in making preparation for systematic ventilation.

The late houses of Parliament, the new houses, St. George's Hall, and the new assize courts at Liverpool, a building in which there were upwards of a hundred public and private compartments, and the experimental rooms and lecture room he had previously constructed at Edinburgh, presented in their combined history the most extended illustration of the applications of his views. The obstacles opposed to them at one place, and their execution in another, under such a variety of circumstances, exclusive of law pleas, arbitrations, parliamentary, professional and other inquiries, called forth facts which elucidated the progress of all the leading questions affecting warming, lighting, ventilating, drainage, and acoustics, in connexion with the progress of modern architecture, and the difficulties they had to encounter.

A diagram was then explained, illustrating the numerous rooms subjected to the action of a single shaft at the late houses of Parliament, and the manner in which it was applied in acting, at the same time, on the chimney flues, on the drains in the vicinity, and on vitiated air when accumulated in the contiguous court-yards. Plans and sections were also shown, illustrative of the works executed under his direction at the new houses, which were incorporated with the principal portions, till he refused to be responsible, and ceased to act, except under protest. The sections explained the portions of the Victoria and the clock towers set apart for the supply of fresh air from a great altitude, the central air chamber under the central hall, the leading channels from it to the House of Peers, to the House of Commons, and to other parts of the building, and the passage for vitiated air from several hundred different places, and from all the smoke flues to the central tower above the central hall, which had been introduced expressly at his suggestion, but subsequently so reduced and cut off from important channels that it formed one of the principal causes of dispute.

The plans showed the general disposition of the fresh air chambers in the vaults, and the great smoke and vitiated air flues in the roof.

Dr. Reid then concluded his remarks on the new houses of Parliament, stating that though alterations had been made in his plans every succeeding year had confirmed him in the opinion that they could not depart in any material point from the principles he had advocated or the practice he had introduced without injury to the ventilation. He added that he had reason to believe that this conclusion would be placed beyond all question whenever the evidence taken at arbitration should become better known; referring to the numerous works he had executed, and to the extent they had influenced others, he mentioned one architect, Mr. Thomas Brown, who had applied his plans in forty-eight public and private buildings.

A large plan was then brought forward showing the details of the principal works executed under his direction at George's Hall, Liverpool. The principal air channels were about 400 feet long, and of such magnitude that any one could walk in them without inconvenience. A central engine commanded the movement of air, and drove four instruments that directed currents north or south, east or west, as might be required. The great hall, the courts of law, the minor courts, the library, the concert room, had the combined advantages of a plenum and vacuum movement. Heat was given by coils of hot water apparatus, the principal coils being each forty feet in length, ten in breadth and six in depth, and auxiliary coils of steam pipe were placed locally, whose action was brought into play principally in very cold weather. Many portions of the structure showed special modifications in the design of the interior for ventilating purposes. All the smaller apartments had fire-places supplied with a soft coke that gave no smoke, and the flues were all carried into four large shafts in the angles of the great hall. No windows were ever opened in the great hall, law courts, or concert room, but in most of the minor rooms and offices windows were made in the usual manner.

When air is supplied to large buildings, or, indeed, to any habitations by a fixed and definite channel, it is very desirable, if it be not introduced from a great hight, to pass it through a gauze in winter, in such towns as London and Manchester, so as to exclude a large portion of the soot that usually accompanies it at such periods. By taking the additional precaution of making it traverse a heavy artificial shower of water, which is still more purifying, if charged previously with as much lime as it can dissolve, the air becomes much more refreshing.

Thus, then, in public buildings of the highest importance the great objects are, the supply of the purest accessible atmosphere; the purification of the air when requisite; the exclusion of all sources of local contamination; the power of warming by a mild heat; the power of cooling; valves and channels that admit of air being changed in temperature at a moment's notice, or, at least, sooner than numbers can pass out of or into the building ventilated; means for moistening air; the ventilation of lamps, or the adoption of a system of lighting that excludes the products of combustion; the introduction of a plenum or vacuum power, or of both, for regulating the supply of fresh air and discharge of vitiated air; and the adoption of the most extensive

measures practicable for securing the supply of air with the gentlest movement, and through a very large diffusing surface, which is more and more agreeable in proportion as it approaches universal diffusion from every perpendicular surface. The diffusion may, in some cases, be given at the ceiling, under certain circumstances of breadth and height, excepting such area as may be reserved there for the discharge of vitiated air.

Leading facts were afterwards pointed out in reference to other classes of buildings, in which his plans had been introduced, from which the following selection is made:

The Chapel Royal, at St. James's Palace, is ventilated by a metallic shaft, worked by a series of gas lights, and the principal fire-places discharge vitiated air into the same flue, with which they communicate by copper tubes. There is an ascending movement of air in the body of the chapel, but in the Queen's gallery the fresh air descends from the ceiling and spreads horizontally over the seats.

At the Pavilion, in Brighton, ventilation was effected by the introduction of an iron shaft, heated by gas, and attached to one of the turrets in the vicinity of the Minarets.

At Buckingham Palace, in ventilating some of the state apartments, a central shaft, having an area of twenty-seven feet, was formed where only two feet of discharge had previously been provided, exclusive of doors and windows. A back staircase, eight feet in diameter, was appropriated for the discharge of vitiated air from the basement and contiguous offices, which had previously flooded the state apartments.

At the opera, in London, a discharge two feet in diameter was replaced by another of seventy-five superficial feet area, but nothing was done for the better supply of fresh air, except at the Queen's box. The proprietors would not agree to give a proper supply.

At the Old Bailey the whole of the arrangements were adapted to the action of a large fanner, eighteen feet in diameter, which was worked by a steam engine.

In churches, the spire or tower was brought into action as a ventilating power, whenever permission was given for this purpose; and when the church was surrounded by a grave-yard or other source of vitiated air it was recommended that the spire should be so divided within that one part might supply fresh air from a considerable altitude above the level of the ground, the other portions being used for the discharge of vitiated air at a higher level.

In prisons, Dr. Reid had used the ventilating shaft principally, and preferred an ascending movement in the individual cells, allowing the prisoner the control of the window to a limited extent.

In barracks for soldiers great suffering was often experienced from defective ventilation, and the men often became practically familiar with this question from the extent to which their arms and accoutrements rusted in some places compared with others, entailing on them a degree of labor, in preparing for parade, of which they made more complaints than of its influence on their health.

In schools, he preferred the action of a single ventilating shaft sufficient to control the ventilation of every apartment in the building, and urged also the general adoption of one regulating discharge from

each room. Illustrations were taken from schools in Westminster and other places, and cases cited where excessive crowding had led to six times the number originally intended being accommodated in particular schools. In this country his own observation, as well as the concurring testimony of different reports he had seen, led him to the conviction that much was still to be done before the ventilation of schools could be considered on a proper footing. The supply was, in general, too small, the means of discharge not sufficiently powerful, and the ascent of the warm entering air so rapid, that much of it escaped by the ceiling without doing any good, unless made to descend to the floor by opening the discharge there, and closing the aperture above, when the products of respiration descended along with it. The diffusion of heat, also, was rarely general and equal, and hence it was often impossible to give sufficient fresh air without opening the windows at times when the state of the external atmosphere indicated that they ought, if possible, to be closed. In some more recent cases the diffusion of heat had been very much extended and improved, but not the ingress of air.

In hospitals much required to be done, more especially where contagious diseases were treated; he considered that great improvements might be made in such cases by causing all the expired air and exhalations to pass directly from each individual patient to a ventilating flue, where, by the action of heat, every noxious emanation could be entirely destroyed, so as equally to save life within doors and relieve apprehension without. In this country, at the New York Hospital, he had seen arrangements that were in advance of most of the plans usually adopted in Europe; but he had not hitherto observed any hospitals where the views he recommended for quarantine hospitals on shore and others for contagious diseases had been introduced.

In chemical lecture rooms, experimental class rooms, and in all manufacturing operations, where acrid, poisonous, or irritating gases and vapors were diffused, he recommended that provision should be made for the direct removal of every offensive product without permitting it to escape into the general atmosphere, illustrating this department of the subject by a large plan of the ventilating shafts and flues introduced at his former class-room in Edinburgh.

From these illustrations it would be seen that the course he recommended was a special adaptation in each individual class of building to the purpose for which it was erected, and in unison with the style of architecture adopted. Air could be made to move in any direction that might be required, and when in a proper condition as to temperature and moisture, and in sufficient quantity, many of the details were often matters of indifference. But the economy of each individual movement was a very different question, and extensive ventilating movements could only be most successfully and economically combined when incorporated with the original design before the building is commenced.

Dr. Reid then passed to the subject of lighting public buildings, and commenced his illustration by throwing a very powerful lime ball light on the flame of candles, lamps, gas-lights, burning alcohol, and

paper. These, under the influence of the lime ball light, gave a shadow on the adjoining wall which did not terminate with the outline of the flame, but merged without any line of demarcation at the upper part of each flame in a continuous ascending undulatory shadow that reached to the ceiling of the lecture room. The apparent shadow arose from the refraction produced by the heated current of ascending vitiated air, and the necessity was then pointed out of all lamps used in public buildings being ventilated by special tubes, or of ventilating apertures being arranged for the discharge of vitiated air above them, so as to prevent the recoil and descent of vitiated air from the ceiling. In an assembly for the transaction of business, in a church, in a school, in courts of law, and in other similar collections, it was too often forgotten that the object to be attained by lighting was not so much to show a beautiful chandelier as to illuminate the countenances of those who took a prominent part in the proceedings.

A visible light close to any object, or in the direct line of sight between one person and another, interfered with distinct vision. In a light-house the light was the special object of attention, as in fireworks, and in various optical, electrical, and chemical experiments; but in public buildings, such as had been adverted to, the less the actual flame or luminous matter was seen the better, provided the proper objects were well illuminated. The more successfully the diffused light of day was imitated, and the light by night corresponded with the light required and given by day, the more satisfactory would the result be. But many were the buildings in which the light by day as well as that by night was very imperfectly adapted to the necessities of the case. In his experience, at least, he had often seen the back of the head illuminated more powerfully than the countenance, and a distraction of rays and beams of light utterly at variance with that harmony and unity of effect that was always manifested in an external landscape, when there was no disposition nor attempt to gaze upon the sun itself in its meridian splendor. The different steps in the progress of this question were then explained; the successive experiments made at Edinburgh, Liverpool, and London, and the final acknowledgment of the principle that the products of combustion from lamps, as well as the heat they produced, should be excluded or withdrawn as much as possible from ventilated buildings, where the heat was not rendered useful in unison with proper ventilation. That electrical lights, oxygenated lights, lime ball, and other lights of great intensity, were not so much required, at their present expensive cost, as a mild and diffused light illuminating the objects to be seen, and which should not glare in the eye of the observer. That the countenance should be illuminated by rays extending from an expanded surface, and rather from above downwards, than from below upwards, always securing, directly or indirectly, as much horizontal light as was required. That lights at a low level, as foot-lights, such as are common at theatres, give an unnatural expression to the countenance, and also interfere materially with distinctness of vision when hot currents of air are permitted to ascend from them, by the inequality of the refraction of light transmitted through such heated currents and the contiguous colder air. That the new resources placed

at the disposal of architecture by the progress of practical science, and particularly by the facility which iron and glass afford in arrangements for lighting and ventilation, call for a revision of the practice of former days and for the more extended use of external illumination, or the introduction of ventilated lamps. That phosphorous was an element that might be advantageously introduced for the purpose of artificial illumination, the acid formed by its combustion being condensed by ammonia, and returned again by chemical processes in the form of phosphorous. There was no objection to bright lights if the rays from them were sufficiently diffused before they met the eye; but until economy was attained in their construction and management, a double expense was incurred, first in producing them and subsequently in moderating their intensity.

The physical effect of light upon the constitution was then adverted to, and illustrations given from a barrack in St. Petersburgh, where a very marked example was presented of this influence in the prevention of disease. If the rays of light were capable of producing those striking and delicate results that were portrayed by the daguerreotype and the photograph, it would be unreasonable to suppose that their action on the sentient fibres of an organized and living structure would not be still more marked. The influence of light was equally conspicuous on the animal and vegetable kingdom; and the tint given to rooms could be used in some cases of disease as a power in assisting to sooth and subdue an irritable temperament, or in raising, in some degree, the spirits of those that were depressed. He had had, on different occasions, the opportunity of noticing the effect produced in this manner. A room that was of a dead black, and another in which pink and white alternated, were at the extremes of the scale.

The electric light was the most intense and penetrating artificial light hitherto discovered; and next to it came the lime ball light. The electric light was accompanied with a perpetual vibration that had not hitherto been overcome; but the lime ball light could be sustained indefinitely and with great equality, by the use of appropriate apparatus. The late Sir John Leslie had estimated that the brightest lime ball light had only a one hundred and twenty-third part of the power of an equal amount of solar radiation.

This lecture was concluded with an account of some experiments he had directed for illuminating the hills at Edinburgh on the occasion of a public festival, when the scenery was made manifest by tons of blue light and other deflagrating mixtures, fired by signals on selected spots on different hills. Nearly a hundred persons were employed on this occasion, and the magnificence and beauty of the effect produced, where isolated landscapes started suddenly into view in the midst of the surrounding darkness, and where the illuminating lights were not seen, confirmed the views he had advocated in reference to the lighting of public buildings. He did not mean to say that naked lights should not be used, and that the light itself should not be visible in all kinds of public buildings. This was not requisite; nor was it so economical. Lights, also, were pleasing adjuncts in the ball room and on all festive occasions, where their sparkling brilliancy added to the gaiety of the

scene. In this respect the pure white wax candle, with its brilliant flame, was unrivalled, except by the small gaslight burning with similar lustre. But he did maintain that the best style of lighting is that which told least on the nervous system and on the health of those who were engaged in public assemblies, and one that was, at the same time, the best for the transaction of public business. The light itself should be altogether concealed, or at least very considerably out of the direct line of vision. He would only add that light transmitted through ground glass was very offensive to some, and that a smoother and opalescent material gave it a softness of tone that could never be commanded by the ground glass. Light radiated from invisible burners, and, falling upon convex plaster of Paris surfaces and solid flowers made of the same materials, and tinged to any agreeable tone, gave a very pleasing and diffused radiation, with which any desirable amount of illumination could be obtained for public buildings.

SEVENTH LECTURE.

In this lecture Dr. Reid commenced with an explanation of the manner in which fire-proofing interfered with the ventilation of some public buildings, and the method of obviating the defects arising from this source. The whole question of fire-proofing required revision. An examination of the construction of different buildings said to be fire-proof would exhibit a great diversity in the standard aimed at, and in the amount of security given against fire. Ventilation required the ingress and the egress of air. Some systems of fire-proofing contemplated the entire prevention of such movements when not in actual occupation, and therefore valves (doubled, if necessary, for additional security) were requisite to cut off all communication with the air flues. The importance of separating contiguous rooms or buildings by fire-proof walls and floors was universally recognized. But the great point desirable in public buildings was to use no combustible materials, or a portion so small that even if on fire it could not do any material injury. These also could be charged with chemicals of different kinds, so as to diminish their ready accendibility. Various experiments were then made illustrative of the action of alkaline and earthy salts in preventing or retarding the combustion of wood, cloth, and other inflammable substances used in building or for furniture. Many fires originated not merely from carelessness, but from an ignorance of the first principles of chemistry. In the present state of society, in which the extension of art and science had introduced the use of so many new materials, it was essential that the chemistry of daily life should be made an elementary branch of general education.

A number of special facts were then mentioned in illustration of this position. It would give increased power and facility in conducting operations of art, and in dealing with combustible and explosive materials. To illustrate this, a portion of gunpowder was placed in a small copper cup, and covered with oil of turpentine. The oil of turpentine was then inflamed. It continued to burn above the

gunpowder, which was not at first in any way affected by it. The flame was blown out, and rekindled. This was repeated several times in succession. At last the gunpowder was exposed, the level of the burning fluid having descended below the surface of the central portion. Still it did not fire; it was surrounded and enveloped in a vapor of oil rising rapidly from the portion below. At last, the oil being nearly consumed, and the edge of the flame coming in contact with individual grains, they deflurated one by one, and soon afterwards the rest of the gunpowder exploded.

This experiment was then varied by placing a small portion of gunpowder on a flat brick, drenching it with oil of turpentine, and sustaining continually around it a small portion of this fluid. A light was then applied, when the oil alone was kindled; the gunpowder acting as a wick, and remaining totally unaffected so long as there was any oil in the vicinity to be consumed.

It was then argued that general instruction in chemistry would give a similar power of control over many sources of fire, and that the principles he had explained in connexion with this illustration could in many cases be practically applied. It would also lead to the more extended use of fire-proof or incombustible materials in all classes of building, by giving correct views as to their nature and capabilities, and the advantages attending their introduction.

The next subjects were the ventilation of underground mines and of ships. These presented peculiar and somewhat similar difficulties, from the comparative inaccessibility of the lower portions of both to the direct access of atmospheric air.

In the class of mines to which he adverted, the great difficulty lies principally in the expense of making ventilating shafts, particularly where springs of water interrupt their formation, or the presence of fire-damp render it important to have a larger amount of ventilation than would otherwise be requisite. Nothing would contribute so much to the better ventilation of mines as the invention of machinery and apparatus for facilitating the sinking of shafts. The attention of men of science and practical engineers should be directed specially to this subject. Hitherto he had not had the opportunity of visiting mines in this country, but he had examined many mines in Great Britain, more especially in the northern mining district, on which he had reported officially when acting on a commission of health for cities and populous districts in England and Wales. In some of the most dangerous mines in England a very slight interruption to the ventilation, or a fall of the barometer, causing a rapid discharge of fire-damp from the coal, greatly increased the risk of explosion. Hundreds were at times subjected to the most horrible deaths, the mixture of fire-damp and air in numerous mines constituting, at the moment of explosion, a kind of aerial gunpowder that equally surrounded the body and penetrated to the interior of the chest. In no range of cases where ventilation was an absolute necessity would education in science do more good than in the mining districts. It was not enough to have a few able superintendents here and there. Every mine and every district of a mine ought to be much more frequently examined

and reported on than was customary at present. He had found in some cases, even recently, that the fresh air intended for the supply of a pit, where there were hundreds of men at work, was contaminated largely when the wind blew in a particular direction from a large heap of waste fuel of inferior quality that had been burning there for many previous years. He mentioned this merely as one of the numerous instances which could be pointed out of the impossibility of checking evils of great magnitude, where more intelligence did not prevail in respect to the nature of the materials which were employed.

One of the shafts of access to the pit, or mine, was usually converted into a ventilating flue, by kindling a large fire, not at the bottom of the pit, but at one side, near the bottom. From this a large flue conveyed the vitiated air and products of combustion to the shaft, at a sufficient distance above the lower part to permit them to cool on the way to a degree which would allow men and materials to pass safely up and down the shaft. Dangerous atmospheres were sometimes diluted with air, by proportionate ventilation, so as to take away all risk of explosion; or discharged by a separate shaft, or by a separate channel, into the ordinary ventilating shaft, far above the fire, so as to prevent their coming in contact with flame. Mechanical appliances were used in some mines to promote ventilation, and advantage had also been taken in different places of the steam jet. Choke damp (carbonic acid) infested numerous mines, and was frequently a cause of death. The Davy lamp, though an invaluable invention, was not always to be trusted, even with all the improvements that had been suggested in recent times. An infinitesimally small particle of carbon might be projected, sufficiently hot from the flame of the lamp, through the wire gauze, by a sudden commotion of the air arising from the falling in of any portion of the roof of a mine, or any other cause, and be fanned into an active combustion in an explosive atmosphere, though ordinary flame is entirely arrested by the wire gauze proposed by Davy.

Again, in many mines, partitions of wood giving way, from the decay of the material, rendered the ventilation less effective; and, in short, from the length of the air courses, extending sometimes to ten, twenty, or thirty miles, the underground miner almost always worked in an atmosphere more or less contaminated; and he did not consider that sufficient exertions were made at present, either by the extended application of practical science, or by the education of the miner, to place this subject on the footing demanded both by the dictates of humanity and by a true economy as a matter of business.

The ventilation of ships had made less satisfactory progress, probably, than that of any other cases in which ventilation was so important. From the time of Dr. Hales, who had long since entered on this question practically, with great ability, and at a period when much of the information now made accessible by more modern chemistry was not available, it had at different periods been taken up, and again neglected; and even in his own experience he had seen it alternately prosecuted with vigor, and abandoned by successive directors of the same board, according as their appreciation or want of information as to the laws of health had dictated. The sea had had its "black

holes of Calcutta" as well as the land. In some cases almost every individual confined under deck, in a storm, had been literally suffocated in consequence of the want of fresh air. Even a very few years ago a case of this kind had occurred in the Irish channel. Still more recently hundreds of Chinese had perished on board ship from the same cause. During the late Crimean war, the suffering and death on shipboard, during a storm in the Black Sea, had been extreme. In one of the most crowded vessels, where defective ventilation added its horrors to disease, nearly a hundred perished in a single night. How often was it forgotten that a very small cause would put out the feeble flame of life, when it had to struggle at the same time against disease and against a vitiated atmosphere, poisoning the very fountain at which it should be renewed at the rate of twelve hundred respirations every hour. If it had been right in him to advocate the cause of general education in the elements of science in speaking of other cases where ventilation was necessary, it was still more essential that it should not be forgotten as a means of promoting the purity of the air of ships.

On examining the condition of ships-of-war, packets and merchant vessels, when his attention was first specially directed to this department, he had not met with a single case in which any arrangements had been made beyond the windsail, and occasionally a few copper or other tubes, acting locally for the supply or discharge of air, and not generally on the whole ship. The effect of these was entirely dependent on the state of the wind. There was no ventilating power that could be put in operation in calm weather, sufficient to meet the contingency of a storm when all side ports and scuttles were closed, and even the very hatches battened down to prevent the ingress of water from the deck. In experiments which he had made on board the Benbow, a seventy-two gun ship, by the kindness of Admiral Houston Stewart, he had used a fanner that sustained a plenum current in a tube made of canvass about four or five feet in diameter. He had afterwards seen a small fanner introduced by Captain Warrington, who had been strongly impressed in a voyage from India with the necessity of the ventilation of ships. But whether fanners, screws, pumps, or any other variety of mechanical power was used for this purpose, a system of tubes or ventilating channels was absolutely essential to admit of a satisfactory effect being insured, particularly on those occasions when ventilation was most imperiously demanded. A ventilating power worked by heat alone was not so generally available on board ship as other means; still, however, it could be used with advantage in many cases when judiciously applied, and the cooking stove could often be rendered useful for this purpose by intelligent officers. In steamboats, the machinery and the fires for the production of steam gave twofold facilities for ventilation. It was inexcusable, therefore, that they should not be more systematically ventilated than they generally were. Any amount of appropriation, almost, could often be secured for the most superb cabin decorations, while a comparatively trifling sum was as often denied for the means of giving the pure breath of life.

A diagram was then shown illustrative of the plans executed by

the directions of Dr. Reid in different classes of ships. Those introduced in two of the Queen's yachts were specially mentioned, and that in the Minden, the hospital ship used during the former Chinese war. He referred also to three steamers he had ventilated for an expedition to the Niger. Emigrant ships and packets were then mentioned, and it was strongly urged that were nothing more done than the introduction of a single ventilating tube from stem to stern, a great and important improvement would be secured. By this, with appropriate power apertures, and with valves, vitiated air could be extracted from any part of the ship in the line of the tube.

At the same time he deprecated the idea that this should be the only improvement introduced where many were crowded in cabins or small spaces. A ventilating tube should be supplied to every individual cabin or place occupied by passengers, and indeed to every isolated portion or cavity of the ship. And in large vessels, with crowded decks, the officers should be instructed in the best methods of converting the ladder ways and cargo hatches into ventilating shafts in proportion to the numbers present. Nor was it difficult to construct temporary air pumps or fanners to assist in the discharge of vitiated air, though it would be much better to have these made on shore and kept in readiness for use on shipboard.

The important question of quarantine was then introduced and its relation pointed out to the subject under consideration. The want of systematic ventilation in ships and the deficiency of chemical information in respect to the necessity of removing moisture, to a certain extent, at least, from different articles of merchandise, occasioned an annual loss in this country alone that would probably, if he was correctly informed, be counted only by millions if all the circumstances of the case were fully taken into consideration. It was most important that an effective quarantine establishment should be maintained, and that hospitals should be so constructed that all the vitiated air from them should be passed through fire, or so altered, at least, by heat or chemicals, as to prove as unobjectionable as air escaping from an ordinary habitation. The introduction of ventilation that would remove the vitiated air from each patient laboring under a severe form of any disease rendering him liable to quarantine, was peculiarly important in quarantine hospitals. It would contribute not only to the health of the patient and to that of the attendants and of the other patients in the same ward, but would tend very much to relieve those without from all apprehension as to the escape of any dangerous atmosphere from the precincts of the hospital. But it was still more important to the public, to the merchant, and to the sailor, that a right system should be adopted in the shipping of all goods prone to convey disease from an infected port, or develope it during a voyage. He contended that this object would be greatly promoted by simply drying, to a certain extent, before shipping them, special classes of exports, and by the introduction in all ships of a ventilating tube from stem to stern, such as had been explained.

Another important measure that should be adopted at all great mercantile ports consisted in providing a portable ventilating appa-

ratus that could be placed on the deck of any ship arriving in a very bad condition, and capable of destroying all noxious effluvia escaping from it, while maintaining as effective a ventilation as circumstances might permit. It was also strongly urged that a steam-tug should be provided at such ports capable of meeting all extreme cases at once, of discharging vitiated air with a power that would make the effect manifest in a few minutes, and also of applying warm, cold, or a fumigated atmosphere to the whole or any part of the ship.

Finally, a special provision should be made on the quarantine grounds for the reception and purification of all suspected goods which it might be necessary to land or to destroy. Many were the cases of disease on shore that had been traced to materials or goods thrown overboard. By the action of a heating, fumigating, and ventilating apparatus consuming noxious products, much valuable merchandise might soon be restored, and worthless materials consumed without danger.

By these varied arrangements the sick could be at once conveyed on shore to a proper quarantine establishment in a ventilated tug, merchandise purified on board ship or on shore, and the public good secured with the least possible tax on the mercantile interest. It was more peculiarly the province and duty of the merchants themselves to have their goods so shipped and their vessels so ventilated as to reduce to a minimum the chances of loss by detention at quarantine, to say nothing of the claims of humanity; and the public could not look on with apathy, either at the loss of life arising from preventible disease on board ship, or the necessity of incurring extreme expense beyond what was necessary for the most effective quarantine establishment.

In concluding these remarks, Dr. Reid took occasion to notice the general condition of the life of the sailor at sea, the hardships to which he was so often subjected, the magnitude of the interests involved in the right construction, management, and efficiency of ships, and of the practicability of immense improvement in this department, more especially in the mercantile marine of all nations. The diminution of shipwrecks, and the prevention of loss were not the only objects requisite. The service should be put on a better footing; the public should support nautical schools and schools of naval architecture, on the same principle that they recognized the importance of supporting or contributing to the support of other departments of education. It was hard to tell what an extended navy and increased commercial relations might yet accomplish between man and man. And were they to lose sight of the mariner in carrying out such national objects, even if it were possible to attain otherwise the desired result, was he to be neglected, whether he might be the rough sailor before the mast or the accomplished officer, skilled in all that science could apply either in the management of his own ship, or in extending the boundaries of human knowledge? Where had there been recorded, at sea or on shore, any memoir of a man of a more refined sensibility, of more daring intrepidity, or of more heroic devotion, than that which characterized Dr. Kane; the intelligence of whose untimely death had just arrived, and whose name would ever be cherished with admiration, regret, and esteem, on both sides of the Atlantic.

EIGHTH LECTURE.

The eighth and concluding lecture of this course embraced an outline of a series of experiments on acoustics, and a description of the construction for acoustic purposes of different public buildings which had been designed by the lecturer or altered under his direction. After a short exposition of the leading principles of acoustics, it was contended, though there might be no end to the peculiarity of developments arising from the use of new materials, new designs, and new decorations, that these principles were sufficiently well known to guide construction, particularly if accompanied with adequate provisions for the escape of sound, after it had effected the object desired—a point that had not, so far as he was aware, met with adequate attention till some of the experiments had been made which he had described. Without this escape, or an equivalent absorption of sound, which was not compatible with many structures and decorations, sound continued too often to reverberate and interrupt the distinctness of succeeding sounds. He then described rooms in various parts of Europe, where the sound was audible from five to twelve seconds after the cause producing it had ceased to act; and added that in such places, supposing only three syllables to be pronounced in a second, from fifteen to thirty-six successive syllables were constantly ringing in the ear and modifying or destroying the enunciation of every succeeding word.

In general, sound was most beautifully distinct and clear in a wood or on the surface of the ocean, no returning echo or reverberations interfering with the sweetness or purity of each succeeding note. If a room were built of properly absorbing materials, or lined with those that did not reflect sound, any form could be given to it that the architect required. It would not be powerful in sustaining sound, but, with adequate power, there would be no jarring reflections. If parallel reflecting surfaces were largely introduced and great altitude given, dissonant sounds would equally destroy or mar both speech and music. Good effects were attained when the highest power of reflection was given near the ear of the hearer and the voice of the speaker, the sound that had done its duty being then absorbed or discharged. The object was attained in a still higher degree when the reflection permitted was induced by materials that had the power of vibrating independently of the general structure. Dr. Reid then described the peculiarities of the acoustics in his class-room, and the trials made in it by members of government and of Parliament; passing then to the old House of Commons, which he had treated as an acoustic instrument, using glass and pine wood largely in the interior, and combining universal ventilation with the means of escape, both above and below, for the sound that had done its duty. The temporary House of Peers he had treated in a somewhat similar manner, but there essentially he had introduced largely a resilient surface of sheet iron on both sides of the house, immediately opposite the most important benches, where the tone of speaking and hearing required the highest attention. In the new House of Commons a different series of arrangements had been introduced in opposition to his views,

but the House had no sooner met and tried it for a few days than they declared it was not fit for the transaction of business with the facility they had been accustomed to in the previous house during the preceding fifteen years; and accordingly the ceiling was lowered in the centre, and on every side, the lateral portions of this new ceiling cutting the windows into two parts, the lower portions solely remaining available to the House. Dr. Reid then entered on a number of other points connected with churches and schools which he had been called upon to alter, sometimes increasing the power of sound by lowering the ceiling and other arrangements, and on other occasions diminishing excessive sound by providing means for its escape or absorption. He then adverted specially to the lecture room of the Smithsonian Institution, and complimented Prof. Henry on the arrangements adopted, saying that it was one of the very few lecture rooms where the voice could be enunciated and heard without effort on the part of the speaker and hearer.

Dr. Reid then adverted to the great progress of acoustics in later years, though it had not yet received the same proportionate attention as optics, and gave a number of illustrations of the effects of the voices of different public speakers, from Wellington and Peel to O'Connell and Shiel; pointing out also the leading peculiarities in the voices of Jenny Lind, Rubini, Catalani, and in the violin of Paganini, which he described as wielding the power of an Orpheus in modern days, and as having exceeded in his opinion rather than fallen short of the almost fabulous terms in which it was often mentioned.

A brief review of the whole question of architecture was then taken, and the necessity shown for combining utility and economy, as well as true beauty and harmony of structure. The great questions of acoustics, lighting, warming, and ventilating might be mutually interwined or accommodated to each other, and perfected with the design and decorations as much as was necessary, before any building was commenced. The principal desiderata necessary for the future progress of architecture were next adverted to; the importance of establishing colleges or special curricula in existing schools for civil and naval architecture, and the immense amount of valuable information and experience at present lost from the want of such establishments were pointed out; universal education in the elements of science was urged as equally important to health, arts, and manufactures, and the extended organization of architectural, agricultural, polytechnic, and industrial institutions.

Dr. Reid then referred to a paper that he had recently published on a college of architecture in the American Journal of Education, edited by the Hon. Henry Barnard, and thanked his audience for the interest they had taken in his exposition of the views he had advocated. He concluded his lectures with the following outline of the course of study recommended for students of architecture:

CURRICULUM, OR COURSE OF STUDY RECOMMENDED FOR STUDENTS OF ARCHITECTURE, BY DR. D. B. REID.

I. General Studies, referring to the materials of which the globe is composed, their power and capabilities, and their relations to the human frame.

1. Chemistry—history of the elements of which the globe is composed, and of their combinations.
2. Mechanical philosophy, including the mutual relations of solids, liquids and gases.
3. Heat, light, electricity, and magnetism.
4. Mineralogy and geology.
5. Meteorology.
6. The general structure and physiology of the frame of man—principles of hygiene.

II. Special Studies.

1. The materials used in building, natural and artificial—their strength and capabilities.
2. The principles and practice of design and construction—the different orders and styles of architecture.
3. Outline of the history of architecture as a fine and as a useful art—the monuments of antiquity—the peculiar works of modern times.
4. Public buildings, including schools, churches, law-courts, prisons, hospitals, theatres, and gymnasia for exercise and recreation.
5. Habitations for the people—extreme importance of the tenement question, and of the right construction of the habitations of the poorer classes in all large cities; its relation to the wants, habits, and morals of the inhabitants.
6. Special buildings for trades, workshops, and manufactories.
7. The construction requisite for acoustics, warming, cooling, lighting, ventilating, fire-proofing, draining and sewerage, the collection and removal of refuse, and the importance of due provision being adjusted for all these purposes before the execution of any building is commenced.
8. The selection of sites for buildings, superficial drainage, the peculiarities required in different classes of foundations.
9. The special architecture required in destroying noxious fumes and exhalations from drains, manufactories, and other houses, and for facilitating the cleansing of large cities and villages, and the general preservation of the public health; the objects and conduct of quarantine on shore.
10. The principles and practice of decorations—the influence of colors.
11. Plans, drawings, and specifications; architectural books required in conducting business accounts.
12. Preparing estimates and measuring executed work.

III. It is presumed that the student will carry on a systematic series of exercises in drawing perspective as well as plan drawing, including isometrical perspective, that he will equally pursue his mathematical studies in relation to every department of the profession which he may have to cultivate, and engage as soon as his time permits, or so adjust his studies as to enable him to become an apprentice to an architect, where he can see daily the realities of his profession. On the whole, however, nothing should be undertaken, if practicable, that will interfere with the right prosecution of his studies.

IV. Lastly, a workshop and laboratory should be provided, in which the student shall have the opportunity of becoming practically acquainted with experimental chemistry, carpentry, and mechanics generally, and be enabled to test materials, and make or direct the construction of models that will facilitate all his labors.

SYLLABUS OF A COURSE OF LECTURES ON PHYSICS,

BY PROFESSOR JOSEPH HENRY, SECRETARY OF THE SMITHSONIAN INSTITUTION.

PART FIRST.

INTRODUCTION.

(1.) SCIENCE, properly so called, is the knowledge of the *laws* of *phenomena*, whether they relate to *mind* or *matter*.

By *mind* we understand that which *thinks*, *wills* and is capable of moral emotions—by *matter* that which *affects our senses*—by the term *phenomena* a collection of associated facts; and by *law* the relation which pervades a class of facts, or a general fact in reference to the order of succession or the method of production of the phenomena.

(2.) So far as these laws have been discovered and developed, they constitute the SCIENCE of the present day.

The study of the laws of the phenomena necessarily includes that of the phenomena themselves.

The mere description and classification of facts belong to Natural History.—[*Novum Organum.*]

The test of a knowledge of true science is the ability to predict what will happen when the circumstances are known.

(3.) General science is separated into two divisions corresponding to the two great objects of thought, material and immaterial.

The first is usually called physical science, and the second metaphysical. The use of these terms is, however, conventional. The phenomena of mind, as well as of matter, belong to nature, which includes all existence.

(4.) Physical science or natural philosophy, in the widest use of the term, comprehends the laws of all the phenomena of external nature, but in the progress of knowledge it has been found necessary to divide it into various parts.

It is first separated into the study of the laws of *Organic* and *Inorganic* matter.

The first comprehends *Zoology* and *Botany*, or the phenomena of animal and vegetable life.

The phenomena of inorganic matter are also considered under two divisions, *Celestial* and *Terrestrial*. The first, which also includes some of the phenomena belonging to the earth, is called astronomy.

The phenomena of terrestrial inorganic bodies are farther divided into three parts.

1. *Geology*, including mineralogy, which treats of the laws of the arrangement and constitution of the masses which form the earth.

2. *Chemistry*, which relates to the *peculiar* phenomena of individual bodies; to the laws of their combinations; decompositions &c.

3. *Natural Philosophy*, or *Physics*, the branch of science with which we are to be occupied in this course of lectures, teaches the laws of the *general* phenomena of bodies and of the agents which produce the changes in inorganic matter; such as the unknown cause of attraction, light, heat, electricity, &c.

These divisions of the study of the laws of inorganic matter are conventional rather than real.

(5.) *Science* assumes as its basis that the laws of nature are constant. The same principle is often expressed in other terms; as, 1. The uniformity of causation. 2. Like causes produce like effects. 3. In similar circumstances similar consequences will ensue.

This principle is the foundation of all scientific reasoning, and is collected from all experience by an original propensity or law of the human mind.—[*Young.*]

(6.) Most of the phenomena of nature are presented to us as the complex results of the operation of a number of laws.

We are said to explain or give the cause of a simple fact when we refer it to the law of the phenomena to which it belongs, or to a more general fact; and a compound one when we analyse it and refer its several parts to their respective laws.

(7.) The indefinite use of the term cause, has led to much confusion and error. We distinguish two kinds of causes, intelligent and physical.

By an intelligent cause is meant the volition of an intelligent and efficient being producing a definite result. By a physical cause, scientifically speaking, nothing more is understood than the law to which a phenomenon can be referred.

Thus we give the physical cause of the fall of a stone or the elevation of the tides when we refer these phenomena to the law of gravitation. And the intelligent cause when we refer this law to the volition of the Deity.

In cases where the law has not been discovered, one fact is said to be the cause of another, when the latter, in some unknown way, depends on the former. Before the law of universal gravitation was discovered, the moon was said to be the cause of the tides, but we now say, in reference to this explanation, that the true cause was then unknown.

The intelligent cause is sometimes called the moral cause, and also the efficient cause.

It is to be regretted that the use of the term cause has not been restricted to the efficiency of an intelligent being, to which it alone properly belongs, and from which the idea is derived.

(8.) In the investigation of the order of nature, two general methods have been proposed: the *a priori* and the inductive method.

The *a priori* method consists in reasoning downwards from the original cognitions, which, according to the *a priori* philosophy, exist in the mind relative to the nature of things, to the laws and phenomena of the material universe.

The inductive method, which is the inverse of the other, is founded on the principle that all our knowledge of nature must be derived from experience. It therefore commences with the study of phenomena, and ascends from these by what is called the inductive process, to a knowledge of the laws of nature. It is by this method that the great system of modern physical science has been established. It was used in a limited degree by the ancients, and especially by Aristotle, but its importance was never placed in a conspicuous light until the publication of the Novum Organum of Bacon.

(9.) In the application of the inductive method to the discovery of the laws of nature, four processes are usually employed,

1. *Observation*, which consists in the accumulation of facts; by watching the operations of nature as they spontaneously present themselves to our view.

This is a slow process, but it is almost the only one, which can be employed in some branches of science. For example, in astronomy.

2. *Experiment*, which is another method of observation, in which we bring about, as it were, a new process of nature by placing matter in some unusual condition.

This is a much more expeditious process than that of simple observation, and has been aptly styled the method of cross-questioning or interrogating nature.

The term experience is often used to denote either observation or experiment, or both.

3. *The inductive process*, or that by which a general law is inferred from particular facts. This consists generally in making a number of suppositions or guesses as to the nature of the law to be discovered, and adopting the one which agrees with the facts. The law thus adopted is usually further verified by making deductions from it and testing these by experiment; if the result is not what was anticipated, the expression of the law is modified, perhaps many times in succession, until all the inferences from it are found in accordance with the facts of experience.

4. *Deduction*, which is the inverse of induction, consists in reasoning downwards from a law which has been established by induction, to a system of new facts. In this process the strict logic of mathematics is employed, the laws furnished by induction standing in the place of axioms. Thus all the facts relative to the movements of the heavenly bodies, have been derived by mathematical reasoning from the laws of motion and universal gravitation.

Induction and deduction are sometimes called analysis and synthesis.

(10.) When one system of facts is similar to another, and when therefore we infer that the law of the one is similar to the law of the other we are said to reason from analogy.

This kind of reasoning is of constant use in the process of induction, and is founded on our conviction of the uniformity of the laws of nature.

In the process of the discovery of a law, the supposition which we make as to its nature, must be founded on a physical analogy, between

the facts under investigation and some other facts of which the law is known. One successful induction is the key to another.

We must be careful not to be misled by a mere rhetorical analogy.

(11.) A supposition or guess thus made from analogy, as to the nature of the law of a class of facts, is usually called an *hypothesis*, and sometimes the *antecedent probability*.

(12.) When an hypothesis of this kind has been extended and verified, or in other words, when it has become an exact expression of the law of a class of facts, it is then called a theory.

(13.) Physical theories are of two kinds; which are sometimes called pure and hypothetical. The one being simply the expression of a law of facts resting on experiment and observation. Such as the theory of universal gravitation—the theory of sound, &c.

The other consists of an hypothesis combined with facts of experience. Of this kind is the theory of electricity which attributes a large class of phenomena to the operations of an hypothetical fluid endowed with properties, so imagined as to render the theory an expression of the law of the facts.

On account of the abuse of theory and hypothesis, discredit has been thrown even on the terms. They are, however, of essential importance to the advance and application of science; since few physical investigation can be made without the adoption of some provisional hypothesis; and a good hypothetical theory such as that of electricity is generally the only convenient expression of the law of a large class of phenomena.

Strictly speaking, no theory in the present state of science, can be considered as an actual expression of the truth. It may, indeed, be an exact expression of the law of a limited class of facts, but in the advance of science, it is liable to be merged in a higher generalization or the expression of a wider law.

(14.) Although in accordance with the principles of the inductive philosophy, it is acknowledged that there is no other method of establishing the laws of nature, than by induction founded on experience; yet many writers who profess to adopt this method, inconsistently attempt to deduce some of the most important of these laws from *a priori* considerations.

For example, in works on mechanics we find frequent attempts to prove the laws of motion by an application of the principle of Leibnitz, called the *sufficient reason*, which is expressed by saying, nothing exists in *any state unless there is some reason for its being in that state rather than in any other*. This principle is evidently true in itself, but its application to the proof of a law of nature presupposes in us a knowledge of all the reasons for the particular existence of things.

(15.) Another principal of Leibnitz often referred to by writers on natural philosophy, is that called the *law of continuity*. His motto in reference to this was, *natura non operatur per saltum*—all the changes in nature are produced by insensible gradations. This principle, it is true, expresses a fact of frequent occurrence, yet since it does not rest on a sufficient induction, we cannot consider it as a law of nature.

(16.) It should be recollected that laws of nature are contingent truths, or such as might be different from what they are for anything we know—that they can only be established by induction from facts of experience—that they admit of no other proof than the *a posteriori* one of the exact agreement of all the deductions from them with the actual phenomena of nature, and that no other reason can be assigned for their existence than the will of the Creator.

(17.) It should also not be forgotten that the great test of the perfection of any branch of science, and of the truth of its laws, is the power it gives us of predicting events when the circumstances are known.

(18.) Importance of mathematics in the study of physical science, principally used in the process of deduction.

It is the great instrument of all exact enquiry relative to time, space, order, number, &c. And as the material universe exists in space, and consists of measureable parts, and its operations are produced in time and by degrees, the abstract truths of mathematics are applicable by analogy to the development of those of external nature.

(19.) Importance of experimental illustrations in teaching physical science.

They serve to give a clear idea of the phenomena, and make an indelible impression on the mind.

(20.) The ultimate tendency of the study of the physical sciences is the improvement of the intellectual, moral, and physical condition of our species. It habituates the mind to the contemplation and discovery of truth. It unfolds the magnificence, the order, and the beauty of the material universe, and affords most striking proofs of the beneficence, the wisdom and power of the Creator. It enables man to control the operations of nature, and to subject them to his use.

(21.) We propose to treat of the general subject of natural philosophy in order as follows:

1. Somatology.

2. Mechanics, (Rational and Physical,) including Statics and Dynamics.

3. Hydrostatics and Hydrodynamics.

4. Pneumatics, including Aërostatics and Aërodynamics.

5. Heat, including the Steam Engine.

6. Sound, including the doctrine of vibrations.

7. Electricity and Magnetism, including Galvanism, Electro-Magnetism, &c.

8. Light and Radiant Heat.

9. Meteorology.

Difficulty of giving a clear idea to these different branches; to understand any one of them requires some knowledge of all the others.

SOMATOLOGY.

(1.) Somatology (σωμα and λογος) treats of the general properties of bodies.

A body, a limited portion of matter.

(2.) The general properties of bodies are certain simple phenomena for the most part immediately obvious to our senses, and some of which are essential to our perception of the existence of matter.

In the present state of science we suppose that there are different kinds of matter, endowed with different qualities or properties; that these enter into various combinations, while the quantity of each in the universe remains the same. It is possible, however, that there may be but one kind of matter and that the different properties are the result of the different groupings of its parts.

(3.) The following is a list of the general properties of bodies as recognized at the present time.

1. Extension.
2. Impenetrability. } Necessary to our perception of matter.
3. Figure.
4. Divisibility.
5. Porosity.
6. Compressibility.
7. Dilatability.
8. Mobility.
9. Inertia.
10. Attraction, and
11. Repulsion.
12. Polarity.
13. Elasticity.

(8–11: Ultimate properties according to the molecular hypothesis.)

Of these, impenetrability, mobility, inertia, attraction, and repulsion, are general facts to which many particular facts may be referred.

(4.) The general properties of matter are frequently divided into two classes, essential and contingent properties; but these are metaphysical rather than physical divisions, and different authors are not agreed as to what are the essential properties.

It appears evident, however, that extension and impenetrability are necessary to our perception of matter, or, in other words, without them our senses would not be affected by matter.

(5.) All the general properties of matter are not to be considered as ultimate facts of which no explanation can be given; most of them, as will be shown, can be accounted for by adopting the molecular hypothesis of the constitution of matter.

Besides general properties, different bodies possess peculiar properties which distinguish them from each other; but the consideration of these belongs to chemistry.

Matter is found in three states or consistencies—solid, liquid, and aeriform or gaseous, and to these may reasonably be added a fourth—the etherial.

Terrestrial bodies are divided into three kingdoms—Animal, Vegetable, and Mineral. Also into Organic and Inorganic.

EXTENSION.

(6.) Matter exists in space; bodies occupy definite portions of space and are therefore extended.

Extension of matter in three dimensions.

The quantity of space occupied by a body is called its volume.

(7.) The exact dimensions of bodies are often required in scientific investigations, and to obtain these, various instruments and methods are employed.

The *vernier* (named from the inventor.) Improperly called nonius. In this, small divisions are measured by the difference of larger ones, on two scales. The long graduated rod is called the scale, the short slider the vernier. See model.

As an example let each division on the scale be $\frac{1}{10}$ of an inch, and let 11 of these be equal to 10 of those, of the vernier; then it follows that each division of the latter will be $\frac{11}{10}$ of an inch, and the difference of the two will be $\frac{1}{100}$ of an inch. Now if any two divisions on each scale coincide with each other, the next pair above will differ $\frac{1}{100}$ of an inch, the pair two degrees above $\frac{2}{100}$, three degrees $\frac{3}{100}$, &c.

(8.) Comparator. For comparing lengths of bars.

Micrometer, consisting of a fine screw with a large circular head divided into parts—applied to different instruments.

1. To dividing machine. Examples of use—500 divisions in the length of an inch, on a slip of glass.

2. To spherometer—tripod with micrometer screw in the middle to determine thickness and sphericity.

Gage plate—for ascertaining the thickness of wire and of plates.

Proportional callipers and compasses.

Saxton's moving mirror, for measuring minute changes in length.

(9.) Method of determining interior diameter of fine tubes, by weighing the mercury which it will contain.

Use of a vessel with a bulb and fine hollow stem, as in the thermometer.

Method of graduating irregular vessels into divisions of equal capacity by equal weights of mercury.

IMPENETRABILITY.

(10.) The property in consequence of which no two bodies can occupy the same space at the same time.

Sometimes regarded as an axiom, but rests on invariable experience.

It was not recognized before the time of Archimedes, who made it the ground of his theory of Hydrostatics.

Space without impenetrability is called void space or a vacuum.

Absolute impenetrability not considered by some as an essential property of matter. See Theory of Boscovich.

Illustrations—impenetrability of air; water; solids.

FIGURE.

(11.) Bodies being limited portions of matter must possess figure or form.

Figure and extension are sometimes called the mathematical affections of matter.

(12.) Many bodies possess forms peculiar to themselves.

Forms of animals and plants, are distinctive marks which serve to identify the species.

All inorganic matter is capable of assuming regular geometrical forms called *crystals*. See constitution of bodies.

Amorphous mass.

Liquids and gases have no peculiar form but assume that of the vessel in which they are contained.

DIVISIBILITY.

(13.) Every body is capable of being separated into parts, and these again into other parts and so on, until the portions become so minute as to escape our senses.

Much discussion relative to the infinite divisibility of matter. The demonstrations given in the older books refer to the infinite divisibility of space, and prove nothing as to the actual divisibility of matter.

(14.) It is convenient to adopt the hypothesis that matter is divisible only to the degree of what is called the ultimate atoms. These are supposed to be indestructible, and endowed with permanent properties.

According to this hypothesis a number of *atoms* form a *molecule*—a number of molecules a *compound molecule*, and a number of the latter a *particle*.

Atomic Theory of chemical combination.

Explanation of definite composition of bodies on this theory.

Atomic volumes of different groups of different bodies.

(15.) Actual divisibility of matter carried to a great extent.

Examples of division of metals, &c.

Gold and silver leaf.

Gilding on embroidering thread—a single grain of gold on thread of this kind has been divided into 3,600,000 parts, perceptible through a microscope magnifying 500 times; and each part exhibiting the properties of the metal.

Wollaston's method of making exceedingly fine wire—finest $\frac{1}{30000}$ of an inch in diameter. Hollow glass thread of extreme fineness.

(16.) Divisibility of matter in solution.

One grain of blue carmine tinges 10 lbs. of water, which is calculated to give 60 millions of blue particles—the carmine itself is a compound substance.

Metallic solutions and chemical tests.

(17.) Illustrations from organized bodies.

The thread by which the spider suspends himself is composed of 6,000 single threads.

Diameter of the globules of the blood, which give the red color, 4000th part of an inch.

Ehrenberg has found whole rocks composed of the shells of animals so minute that one cubic line contains about 23 millions of them. These animals must have had limbs and other parts.

(18.) Divisibility of odorous matter.

Our olfactory nerves frequently detect the presence of matter in the atmosphere, of which no chemical test could afford an indication.

A single grain of musk will scent a large room for years.

The dog hunts by the scent of odors imperceptible to man.

A single drop of lavender made to fill a large room.

POROSITY AND COMPRESSIBILITY.

(19.) All bodies can be indefinitely compressed, or reduced in volume; consequently, in their ordinary state, they do not form a *plenum* of matter.

The intervals between the parts are called pores.

If we adopt the hypothesis of the atomic constitution of matter, we must admit the existence of different orders of pores.

Pores between the atoms—between the molecules—between the particles, and between the grosser parts.

Illustrations—shrinking by cold—mixture of liquids—water in sponge.

Improper idea often given of porosity.

(20.) *Real* and *apparent* volume of bodies.

Method of determining the ratio of these.

The sum of all the atoms of a body constitutes its *mass*.

Density is the quantity of matter in a given bulk or volume.

In homogeneous bodies *mass* proportion to the bulk.

In heterogeneous bodies, to bulk and density.

(21.) Absolute quantity of matter in a given body may be exceedingly small.

Illustration—vessel filled with alcohol, great quantity of cotton introduced—sponge dipped in vessel nearly filled with water.

Relative bulk of steam and water; great porosity of the former.

(22.) Porosity of organized bodies.

Mercury forced through a cylinder of oak—pine sinks in water when saturated by pressure—experiments of Scoresby. Skin perforated with a thousand holes in the length of an inch, through which the insensible perspiration passes; water through a bladder. Remarks on India rubber cloth—improper for clothing.

(23.) Porosity of minerals.

Mercury through lead; condensation of alloys; water through gold; water through cast iron; gold leaf translucent. Porosity of chalk—of marble—of hydrophane.

Method of coloring agate.

Effects of water on rocks. Formation of stalagmites and stalactites.

Method of determining whether a stone will stand the effects of frost by the absorption and crystallization of a salt.

(24.) Porosity of liquids:

Water and sulphuric acid; water and alcohol; salt and water; water and gas.

(25.) Porosity of gases:

Air and vapor; nitrogen and hydrogen.

Some bodies are without pores of the third order. Examples: glass, crystals, &c.; but these can be compressed, and, therefore, have pores of an inferior order.

(26.) Compressibility of solids, by mechanical means:

Of iron in casting; of brass for delicate machines; of wood, so as to sink in water; of cork in neck of bottles lowered into the deep sea.

(27.) Of water and other liquids.

Apparatus of Perkins. Of Œrsted. See Elasticity.

(28.) Compressibility of air and all gases.

Experiment with air in a tube submitted to great pressure under water.

DILATABILITY.

(29.) All bodies change their volume with a change of temperature.

Examples: air expanded by heat; also water; bar of metal lengthened; Saxton's apparatus employed.

Preliminary notions of heat.

General description of the thermometer.

Dilatability by the removal of pressure.

Examples in the case of air; water; solids.

(30.) By mechanical exertion.

Examples: When India rubber is stretched, its density is said to be slightly lessened. Also, when wire is drawn in the direction of its length, the same effect is produced.

MOBILITY.

(31.) The property by which a body is capable of a change of place.

Motion is better illustrated than defined. The following definition, however, is sometimes given:

Motion is the rectilinear change of distance between two points.—[*Dr. Young.*]

According to this definition, if there were but one point in the universe, there could be no measurable motion.

(32.) Rest is permanency in the same place.

It is only apparent; all bodies are really in motion, expanding and contracting with the constant change of temperature—moved by every sound; in motion with the earth on its axis and in its orbit.

Rest and motion of two kinds, *absolute* and *relative.*

Illustrations:

Direction of motion; *continued* and *reciprocating; rectilinear* and *circular.*

The line described is sometimes called the *trajectory.*

(33.) In the consideration of motion the ideas of space and time are necessarily involved.

Time is considered as a quantity consisting of parts which can be compared or measured.

Imperfectly measured by a succession of ideas.

Circumstances which vary the apparent rapidity of the lapse of time.

(34.) In the exact measurement of time, the following axiom is assumed—*In the operations of nature the same effects under the same circumstances are always produced in equal times.*

Examples: The fall of a stone from the same height to-day and yesterday; *the successive vibrations* of a pendulum; flowing of equal quantities of sand; the revolutions of the earth on its axis.

(35.) Uniform motion is that in which equal spaces are passed over in equal times.

Motion of the earth on its axis perfectly uniform. From this is derived the principal unit of time—the day; the subdivisions of which give the lesser divisions.

By the whirling mirror less than the $\frac{1}{1000000}$th part of a second can be measured, and yet great physical changes are produced in this interval.

(36.) The *velocity* or *rate* of motion of a moving body, is the ratio of the space described to the time of describing it. Illustrations.

Velocity, time, and space, are heterogeneous quantities, and are therefore compared numerically.

Unity of time and of space—hour, mile—second, foot.

The relations of uniform motion are expressed by the following equations;

$$S = VT; \quad T = \frac{S}{V}; \quad V = \frac{S}{T}. \quad (1.)$$

(37.) Variable motion is that in which equal spaces are not described in equal times.

The velocity may be constantly increasing or constantly decreasing. Two cases of each kind: 1. Variation equal in equal times; 2. Variation unequal in equal times.

INERTIA.

(38.) That property of matter by which it tends to retain its state, whether of rest or motion. [La Place.]

(39.) It has been established by a wide induction that *a body at rest cannot of itself begin to move and that a body in motion cannot change its velocity nor its direction of motion without the action of some extraneous cause.*

This is called the law of Inertia. (See Mechanics.)

It may be otherwise stated as follows:

A body at rest tends to remain continually at rest; a body in free motion tends to move continually (1) with a uniform velocity, and (2) in a straight line.

(40.) *That which tends to produce change, or prevent motion, is called a force,*

Or whatever causes a body to exist under a given condition, or whatever changes any of its relations, is called a *force*.

The muscular exertion of animals, the unbending of a bow, the impulse of a moving body, are instances of active force. The resistance of a rope which suspends a body, of a table which supports a weight, are examples of forces which tend to prevent motion.

Our idea of force is derived from the muscular effort required to produce the motion of a mass of matter.

The original meaning of the word was *muscle* or *tendon*. [Whewell.] It becomes metaphorical when applied in any other case, and we must not, therefore, imagine that force is always connected with labor or difficulty.

Force which is capable of doing work, that is of transforming matter is called power or energy. [See mechanics.]

(41.) In all cases of the change of the state of a body in reference to rest or motion, we can attribute this change to an extraneous force.

The spontaneous motions of animals are ascribed to vitality.

The fall of a stone to the action of the earth.

Two kinds of force, *Impulsive* and *Incessant;* an incessant force may be either *Accelerating* or *Retarding*. Examples.

(42.) Force is measured by its effects.

We usually call that a double force which produces a double velocity in the same mass, or

$$f : F :: v : V$$

We also call that a double force which produces the same velocity in double masses, or

$$f : F :: m : M$$

When the velocities and masses are both unequal, the forces are measured by the product of the velocities into the masses, or

$$f' : F' :: mv : MV$$

The force proportional to the product of the mass into the velocity is called the *quantity of motion* or *momentum*.

An incessant force is measured by the relation

$$FT = V \quad \text{or } F = \frac{V}{T}. \qquad (2.)$$

(43.) It must be observed that the relations here given are the results of experience. We know nothing of force but by its effects, and in some cases we are obliged to adopt the relation

$$f : F :: v^2 : V^2$$

Force is also sometimes measured by pressure.

The laws of force and motion will be fully developed under the head of Mechanics.

(44.) *Illustrations of the foregoing principles.*

Tendency of bodies to remain at rest. Wood split by the inertia of an iron wedge.

Tendency of bodies to continue in motion. The inertia in this re-

spect of solid, liquid, and aeriform bodies. Continued motion of the planets.

Causes of cessation of motion. Friction; resistance; and communication of motion to other bodies. Ball on cloth; also on smooth board. Wheel on friction rollers.

Matter perfectly free to move. Large mass freely suspended, put in motion by impulses from small ball of putty; velocity small in proportion.

Effect of a succession of small impulses. Heavy body put in rapid motion by successive pulls with cambric thread.

Attempt to put a body in a state of rapid motion by a single given impulse.

Motion of large mass stopped by a succession of small impulses. Also, by a single impulse, or by an obstacle.

Term *vis-inertiæ* sometimes used in connexion with this phenomenon.

Tendency of matter to move in a straight line, shown by an experiment.

Experimental proof of uniform velocity of unrestrained motion.

Animals sometimes act instinctively in accordance with the principle of inertia. Hare when pursued by the hounds. Rams in butting. Favorite amusement at the court of Persia.

Means of accumulating momentum in a large mass of matter for purposes in the arts.

ATTRACTION AND REPULSION, OR THE GENERAL PHYSICAL FORCES.

(45.) The tendency in the parts of all matter to approach toward or to recede from each other.

These tendencies differ from the other general properties of matter, in the fact of their being forces acting reciprocally between bodies at a distance from each other, or between the minute parts of the same body. The existence of these forces, in the present state of science is an ultimate fact, although attempts have been made to refer them to the intermediate agent or agents of the phenomena of heat and electricity.

The intensity of the attracting and repelling forces varies with the distance of the parts of matter between which they act, and where the geometrical relation between the distance and the intensity is known, the whole is called a law of attraction.

In the present state of knowledge we arrange the different phenomena of attraction and repulsion, under the following heads, although it is not impossible that they may be the result of one principle.

Atraction of

$$\left.\begin{array}{l}\text{GRAVITATION,}\\ \text{ELECTRICITY,}\\ \text{MAGNETISM,}\end{array}\right\}\begin{array}{l}\text{which act}\\ \text{at sensible}\\ \text{distances.}\end{array}$$

$$\left.\begin{array}{l}\text{COHESION,}\\ \text{ADHESION,}\\ \text{CAPILLARITY,}\\ \text{CHEMICAL AFFINITY,}\end{array}\right\}\begin{array}{l}\text{which act}\\ \text{at insensible}\\ \text{distances.}\end{array}$$

Illustration. Attraction at a distance—action not interrupted by solid matter—attraction and repulsion through the human body. Attraction and repulsion instantaneous.

Variation of intensity with change of distances.

Experiment to show phenomena which appear the result of attraction, but which are due to pressure, &c.

pieces of wood collected together on water not the result of direct attraction.

Attraction of Gravitation.

(46.) The reciprocal tendency of all parts of the solar system to approach each other.

The same action probably extends to other systems.

(47.) Gravitation is an incessant force, and is generally *measured by the velocity which it imparts to the attracted body in a second of time.* May also be measured by pressure. Illustrations.

Newton's Theory of Universal Gravitation. The most extended generalization ever established by man. It may be expressed as follows:

1. *The attraction exists between the atoms of all matter at finite distances, and is the same for all kinds of matter, hence:*

2. *The force of attraction is proportional to the mass of the attracting body; the distance being the same.*

3. *If the same body attracts several bodies at different distances, the forces are inversely as the square of the distances.*

All deductions from this theory are in strict accordance with the phenomena of nature. The only proof of the truth of any physical law.

(48.) In some cases of attraction the whole *moving force* of approach of two bodies is required, and this is as the product of the masses into the inverse square of the distance.

The acceleration of the velocity of approach is as the sum of the two masses, and inversely as the square of the distance.

Illustrations of the laws by diagrams of atoms.

(49.) In reference to the attraction of spheres the following propositions will be proved. See Mechanics.

1. A particle of matter placed without a *solid* homogeneous sphere is attracted as if all the matter of the sphere were in its centre.

2. The attraction is the same in reference to a particle without a *hollow* sphere.

3. A particle placed within a homogeneous hollow sphere is in equilibrio at any point within the sphere.

4. Particles placed at different distances from the centre within the surface of a solid homogeneous sphere are attracted towards the centre with forces proportional to the distances from the centre.

(50.) Attraction of spheroids. Gravitation the most feeble of all attractions; almost imperceptible between small masses; long time required for two lead balls to come together.

Illustrations of the foregoing principles.

The attraction between all bodies at sensible distances proved by the experiment of Cavendish. See Mechanics.

The attraction of all matter the same, shown by an experiment. Also Newton's experiment to prove the same.

(51.) At all accessible distances above the surface of the earth, the diminution of the force of attraction is very small. If R represents the radius of the earth, x the distance, F the force at the surface, and D the diminution, then approximately

$$D = \frac{2xF}{R+2x} \qquad (3.)$$

Small as this diminution is it may be detected by the vibrations of a pendulum on a high mountain and at the level of the sea.

In some investigations, as that of the fall of bodies near the earth, &c., the diminution is neglected, and the force is considered as invariable: in these cases, gravitation takes the name of *gravity*.

(52.) The earth is nearly a sphere, and all bodies fall in straight ines, directed nearly to its centre.

The convergency, however, in a short distance is very small. In a geographical mile it is but one minute of a degree.

The direction of gravity is readily shown by the plumb line.

The *weight* of a body is the aggregate action of gravity on each of its atoms, or

$$W = Ng. \qquad (4.)$$

Consequently the weight of bodies is as the quantities of matter, and also as the force of gravity.

(53.) The absolute weight of a body is estimated in reference to some arbitrary standard, which differs in different countries. In England the grain is the foundation of the system of weights.

Pound avoirdupois	(16 oz.)	7000	grains.
Ounce do.		437½	"
Pound Troy	(12 oz.)	5760	"
Ounce do.		480	"

In order to perpetuate the standard it is referred to the weight of a given bulk of pure water at a given temperature. Thus the English grain is of such a weight that a cubic inch of distilled water at 62° F. in vacuo, is equal to 252.72 of such grains. A cubic foot therefore weighs 62.3862 lbs. avoirdupois.

In the State of New York, by a provisional act of the legislature, the ounce is the standard; and this is of such a weight that 1,000 of them are equal to the weight of a cubic foot of distilled water at its maximum density (40° F.) and in vacuo.

(54.) The ratio of the weight of one body to that of another of equal bulk taken as a standard is called the *specific gravity*.

Pure water at a given temperature is the standard for solids and liquids; air under a given pressure and temperature for gases and vapours.

Simple method shown of determining the specific gravity of bodies—other methods will be given under the head of hydrostatics.

Table of specific gravities exhibited. Hydrogen the lightest substance, and Iridium the heaviest—the first is .069 the weight of air, and the latter 23 times that of water. In equal bulks the weight of the latter is more than a quarter of a million of times that of the former. [Dr. Hare.]

(55.) It is a remarkable fact that the *inertiæ* of equal bulks of different substances are in the same ratio as their weights. Hence the masses, the quantities of matter, and the densities of different substances of the same bulk are said to be proportional to their relative weights; or, in other words, to their specific gravities.

(56.) The absolute weight in ounces of solids and liquids may be obtained by the following relation, in which B is the bulk in cubic feet, and S the specific gravity.

$$W = 1000S \times B. \qquad (5.)$$

The weight of air shown. 770 times lighter than water at the freezing point with bar. at 30 inches. Difference between the weight of air and the pressure of the atmosphere.

Electrical and magnetic attraction and repulsion.

(57.) These are exhibited under certain conditions in all kinds of matter. They will be fully discussed under their appropriate heads. Magnetic attraction may however be here employed to illustrate the general principles of *polarity*.

The attraction and repulsion of a magnet shown to exist at its two ends called poles; hence the term polarity—origin of the name—neutral point at the middle between the two poles—the magnet broken, each part shown to be a perfect magnet with attracting and repelling poles—again each part divided into two pieces, and again the exhibition of new poles, and so on, until we infer that the polarity exists in every part of the mass, or in other words that attraction and repulsion belong to the opposite extremes of every molecule of the metal.

(58.) In order to explain the phenomena of chemical saturation, crystalization, the difference of the liquid and solid states of bodies, as well as other phenomena we are obliged to admit a kind of polarity as a general property of the molecules of all bodies.

Attraction of cohesion and adhesion, or the molecular forces.

(59.) By cohesion we designate the force by which the parts of the same body are held together, and by adhesion that which causes the parts of dissimilar bodies to unite. These forces are also sometimes distinguished by the names of homogeneous and heterogeneous attraction.

(60.) There is also between the molecules of the same body and the parts of different bodies a repulsive action and this with the attractions constitute what are called the molecular forces.

Also sometimes called corpuscular action.

(61.) *Cohesion of solids.*—Two leaden balls made to cohere with a force of 40 lbs. to square inch of surface of contact. Two glass plates shown to cohere with great force—also two plates of marble.

(62.) The relative cohesion of bodies is called the *tenacity*, and this is determined by the weight required to pull apart a bar of the substance an inch square.

This weight is sometimes called the limit of cohesion and a knowledge of it is of great importance in the arts.

Barlow's table of the cohesion of the principal substances used in the art of construction.

Cast steel	134,256 lbs.	Teak	12,915 lbs.
Swedish malleable iron	72,064	Oak	11,880
Good American do	60,000	Sycamore	9,630
English do	55,872	Beech	12,225
Cast iron	19,096	Ash	14,130
Cast copper	19,072	Elm	9,750
Yellow brass	17,958	Memel fir	9,540
Cast tin	4,736	Christiana deal	12,346
Cast lead	1,824	Larch	12,240

Considerable uncertainty in reference to tenacity—much smaller force required to produce rupture, if time be allowed for the action. Explanation of this.

(63.) The tenacity and density of surface of metals are increased by drawing the masses into wire. The cohesion of gold, silver, and brass more than doubled by this process. [*Robison.*] The surface in this case appears to receive a fibrous texture. If the outside be removed by acid the tenacity is materially lessened. Same effect produced by annealing [heating and gradually cooling] the wire.

(64.) The mixture of some metals is more tenacious than the metals themselves. Brass is stronger than its components, copper and zinc. A small addition of zinc to tin almost doubles its strength. In these cases heterogeneous attraction is stronger than homogeneous.

(65.) The tenacity of many substances is greater in some directions than in others. Examples, crystals, wood, &c.

The tenacity of bodies is effected by heat; sometimes increased, sometimes diminished. Iron at first stronger then weaker.

The effect of a small degree of heat on the cohesion of two leaden balls shown by experiment. By the application of a greater degree of heat, the metal may be changed from a solid to a vapor.

(66.) *Cohesion of liquids.*—The relative intensity of cohesive force of liquids may be measured by suspending a plate, which can be wet by the liquid, to the arm of a balance, and attaching weights to the other arm until separation takes place. Dividing the weight thus found, by the number of square inches in the plate, the quotient will give the cohesive force for one square inch.

The cohesion of water for water, shown by the force required to separate a disc of wood. Rupture between water and water. Attraction of water for wood greater than that of water for water.

In the same manner we can find the *relative* cohesion of different liquids. 52 grains to the square inch required for the separation of

water ; 28 grains for alcohol ; and 31 grains for oil of turpentine.
Liquid in drops. Relative size of drops.

(67.) The foregoing method gives us the *relative* cohesion, but not the absolute. It is not the attraction of the whole section of the fluid which produces the result, but that of the indefinitely thin film around the exterior perpendicular surface, and within which the mass of fluid hangs by its cohesion. [*Young, La Place, Poisson.*] Explanation of this: See (89.)

Connexion of the curvature of the surface with this apparent attraction. See Capillarity.

(68.) The molecular attraction of water for water at 32 degrees, is probably greater than ice for ice at the same temperature. The apparent feeble attraction of water for water, is due to the perfect mobility of the particles which permits them to slip upon each other. Explanation of this: See (89.)

Phenomena of adhesion.

(69.) *Adhesion of solids to solids.*—The solder adheres to the metals which it unites. Gold leaf stamped on metals—adheres to glass. Wax adheres to many solids. Bladder dried on glass, the surface of the latter torn by forcibly removing the former.

(70.) *Adhesion of liquids and solids.*—The force required to separate glass from mercury, shown by experiment—the cohesion is here stronger than the adhesion.

Same experiment with a clean surface of copper, the rupture is now between the molecules of the liquid—adhesion stronger than cohesion. The same in case of a solid, wet or infilmed with water.

Stream of water made to follow the under side of an inclined glass tube. Method of pouring a liquid into a vial with small neck.

Explanation of the use of a lip to vessels from which liquids are to be poured. The edge of the vessel touched with grease.

Mercury poured from glass vessel, also from a tinned one.

(71.) Adhesion of solids increased by the interposition of a liquid. The adhesion increased by the solidification of the interposed substance.

A thin flake of tallow cooled between two discs.

(72.) Different liquids possess different degrees of attraction for the same solid.

Film of water driven from surface of glass by a drop of alcohol ; the attraction of the latter for the solid the stronger.

Same effect with oil of turpentine.

(73.) *Phenomena of solution ;* lead in mercury ; sugar in water, &c.; heterogeneous attraction stronger than the cohesion of the solid. Different bodies dissolved in the same liquid.

Effect of pulverizing in hastening solution.—Due to the increase of surface. A cubic inch of matter cut into little cubes, each $\frac{1}{2400}$ of an inch on the edge, will exhibit a surface of exactly 100 square feet. Trituration produces a finer division than even this.

Explanation of the cleansing effect of water.

Displacement of one body by the solution of another. Rosin dissolved in alcohol. Water poured in.

Alcohol dissolves some substances which water does not; and the converse.

(74.) *Adhesion of liquids to liquids.*—Oil spreads on the surface of water. First drop infilms the whole of a limited surface; second drop collects itself into the form of a lens. The film so thin as to exhibit the colors of the soap bubble. Explanation of the spreading of oil on water.

Effect of oil in stilling surface waves. Dr. Franklin's magical cane.

Surface motions—camphor, spirits of turpentine, &c., on water; motion produced by alcohol, oil, &c., in light bodies.

(75.) *Adhesion of gases to solids.*—Air to glass shown by pouring mercury into glass tube—vapor of water to glass—clean surface of platinum plunged into a vessel of oxygen and hydrogen; same effect with other metals slightly warmed.

Rapid manufactory of vinegar; object of dividing the metal.

Adhesion of gases to liquids.—Air absorbed by water; also by melted metals. Shown by pouring the liquid metal into water.

(76.) *Adhesion of gases to gases.*—Between the molecules of the same gas continued repulsion exists; but the molecules of different gases probably slightly attract each other. Diffusion of gases the same as if the one was a vaccuum to the other. [See Pneumatics.]

Molecular repulsion.

(77.) *Examples.*—Two glasses, one slightly convex the other flat, placed on each other and pressed by a force of 1,000 pounds to the square inch are still, at the distance from each other of the thickness of the top of a soap bubble just before it bursts, or at least $\frac{1}{4480}$th of an inch. Method of finding this. [*Robison.*]

Small drops of water rebound from a surface of water. Also alcohol from a surface of the same liquid gently heated.

Solids expand when the pressure of the air is withdrawn, this shown by experiment. Liquids, compressed, spring back to the original bulk when the pressure is removed.

The particles of air repel each other, repulsion increases with diminution of distance.

By a slight agitation of percussion powder it springs into a gaseous state—the particles separate with immense velocity, and repel each other with great force.

The dew drop which rests on the surface of a leaf is not in mathematical contact, but sustained by repulsion.

Repulsion of solids when heated. Experiment with an instrument called the Rocker.

(78.) The molecular attractions and repulsions appear to predominate at different distances. All bodies attract each other at sensible distances, but when brought nearly in contact they repel; still nearer attract and again repel.

Experiments of Huygens and Robison on this point—two very

smooth and flat glasses attracted at one distance, repelled at another, &c. Experiment very delicate; care required to exclude electrical and other extraneous actions.

(79.) The molecular forces are confined to exceedingly small ranges of distances. The alternations above mentioned take place within the 5000th part of an inch. The two plates of glass are brought into the sphere of cohesion by sliding them together, and when strongly pressed for sometime become incorporated as one.

Probable explanation of this.

(80.) Coarsely powdered substances which do not cohere, when finely powdered and submitted to great pressure become solid.

Cannon ball fired into the mouth of a large cannon filled with sand produces sandstone.

Explanation of this.

(81.) Although the molecular action is confined to insensible distances, yet the forces are of the same nature as those of gravitation and magnetism, tending to produce motion in the molecules as the others do in the masses. Proof of this.

Molecular constitution of matter.

(82.) The phenomena of the transmission of sound, of light and heat—of dilatability and compressibility—of porosity, &c., all lead us to adopt the hypothesis that matter under its apparent volume does not consist of a plenum, but that its molecules are widely separated in reference to their size by void spaces; or by spaces occupied only by the imponderable agents or agent of light, heat, and electricity.

The molecules, however, must be supposed to be so small and so near that many myriads of them exist in the length of an inch, and on this account produce on our senses the effect of perfect solidity.

The primary molecules may be supposed to be formed of the union of others of an inferior order separated in the same way and so on as far as the actual phenomena may indicate.

Each molecule must be submitted to the action of attraction and repulsion, and these forces predominate at different distances.

(83.) According to the molecular hypothesis, frequently adopted, the attraction belongs to the molecules of the matter, but the repulsion is due to the atmospheres of the imponderable agent of heat, which is supposed to surround them; or in other words, between the molecules of matter there is attraction, between the atoms of heat, repulsion, and between heat and matter, attraction.

The electrical hypothesis of the constitution of bodies.

(84.) The different states of bodies depend on the condition of the molecular forces. In gases the cohesion is nothing and the particles tend to separate but probably not continually, at a certain distance gravitation would predominate. In liquids the attraction and repulsion are balanced and the molecules have perfect mobility among themselves; but in solids besides cohesion there is another force, *polarity*, which prevents lateral motion while the molecules are free to oscillate.

Atomic theory of Boscovich.

(85.) This is similar to the foregoing and may be expressed in the following postulates:

1st. Matter consists of indefinitely small indivisible and inert *atoms*.

2d. These are endowed with attracting and repelling forces, which vary both in intensity and direction by a change of distance, so that at one distance two atoms atttract and at another repel.

3d. The law of variation is the same in all *atoms*, and the action mutual.

4th. At all sensible distances the force is attraction, and known by the name of *gravitation*.

5th. Within the insensible distance in which physical contact is observed, there are several alternations of attraction and repulsion.

6th. The last force which is exerted between two atoms as their distance diminishes is an insuperable repulsion, no force however great can press two atoms into mathematical contact.

The property of inertia was not assigned to the atoms of Boscovich, but it is necessary to explain the phenomena.

(86.) Use of such a theory—an expression of a limited generalization including many facts—may be continually improved and modified as new facts are discovered. Importance of general views of this kind as aids to discovery.

The theory expressed mathematically—Distances, attraction, and repulsion represented by the abscissæ and ordinates of a curve which cuts the axis several times—parts above the line attractions—below repulsions. The primary branch forming an asymptote expresses a continued increasing repulsion. The final branch gradually assimilates itself to the law of gravitation.

Illustration of the theory.

(87.) Stable and instable points. For small distances the curve may be considered a straight line; the force is therefore inversely as the distance—atoms in stable points are inactive—when pushed nearer they repel—when drawn apart attract.

Formation of a polarized molecule of an assemblage of such atoms—construction of a solid.

Diagram and models to illustrate hypothetical constitution of matter.

Crystalline forms produced by grouping of atoms—development of polarity—attempt to explain the liquid and solid states. Shrinking of ice in melting, &c.

The internal structure of inorganic bodies may be studied, 1st, by cleavage: 2d by the action of polarized light; 3d, by vibrations.

Daniell's method of developing the crystalline structure of amorphous solids. Alum in water. Metals in mercury.

Derangement of the molecules in a rod of glass by bending, shown by polarized light. The extreme mobility of the particles of the most

solid bodies exhibited by the same. Transmission of small impulses through a very long rod of wood.

Atoms set in motion by the smallest force.

(88.) In connexion with the subject of the constitution of matter, the following extract from a paper by the author, published in the Proceedings of the Am. Phil. Soc., may be given.

"The passage of a body from a solid to a liquid state is generally attributed to the neutralization of the attraction of cohesion by the repulsion of the increased quantity of heat; the liquid being supposed to retain a small portion of its original attraction, which is shown by the force necessary to separate a surface of water from water, in the well known experiment of a plate suspended from a scale beam over a vessel of the liquid. It is, however, more in accordance with all the phenomena of cohesion to suppose, instead of the attraction of the liquid being neutralized by the heat, that the effect of this agent is merely to neutralize the polarity of the molecules so as to give them perfect freedom of motion around every imaginable axis. The small amount of cohesion (52 grains to the square inch) exhibited in the foregoing experiment, is due, according to the theory of capillarity of Young and Poisson, to the tension of the exterior film of the surface of water drawn up by the elevation of the plate. This film gives way first, and the strain is thrown on an inner film, which, in turn, is ruptured; and so on until the plate is entirely separated; the whole effect being similar to that of tearing the water apart atom by atom.

"Reflecting on this subject, the author has thought that a more correct idea of the magnitude of the molecular attraction might be obtained by studying the tenacity of a more viscid liquid than water. For this purpose he had recourse to soap water, and attempted to measure the tenacity of this liquid by means of weighing the quantity of water which adhered to a bubble of this substance just before it burst, and by determining the thickness of the film from an observation of the color it exhibited in comparison with Newton's scale of thin plates. Although experiments of this kind could only furnish approximate results, yet they showed that the molecular attraction of water for water, instead of being only about 52 grains to the square inch, is really several hundred pounds, and is probably equal to that of the attraction of ice for ice. The effect of dissolving the soap in the water, is not, as might at first appear, to increase the molecular attraction, but to diminish the mobility of the molecules, and thus render the liquid more viscid.

"According to the theory of Young and Poisson, many of the phenomena of liquid cohesion, and all those of capillarity, are due to a contractile force existing at the free surface of the liquid, and which tends in all cases to urge the liquid in the direction of the radius of curvature towards the centre, with a force inversely as this radius.

The fact of the existence of this force is derived from a consideration of the molecular constitution of matter. The molecules within the mass of a liquid and at a distance from the surface, can be moved freely in all directions among each other, because they are acted on by equal forces on all sides. Not so with the molecules very near the surface, these are separated by the preponderance of repulsion, and

the fluid is rarified both in a vertical and horizontal direction, and by the reaction a tension or contractile force is developed in the whole exterior film.

Explanation of this by a diagram.

"According to this theory the spherical form of a dew-drop is not the effect of the attraction of each molecule of the water on every other, as in the action of gravitation in producing the globular form of the planets, (since the attraction of cohesion only extends to an appreciable distance, but it is due to the contractile force which tends constantly to enclose the given quantity of water within the smallest surface, namely, that of a sphere. The author finds a contractile force similar to that assumed by this theory in the surface of the soap bubble; indeed, the bubble may be considered a drop of water with the internal liquid removed, and its place supplied by air. The spherical form in the two cases is produced by the operation of the same cause. The contractile force in the surface of the bubble is easily shown by blowing a large bubble on the end of a wide tube, say an inch in diameter; as soon as the mouth is removed, the bubble will be seen to diminish rapidly, and at the same time quite a forcible current of air will be blown through the tube against the face. This effect is not due to the ascent of the heated air from the lungs, with which the bubble was inflated, for the same effect is produced by inflating with cold air, and also when the bubble is held perpendicularly above the face, so that the current is downwards.

"Many experiments were made to determine the amount of this force, by blowing a bubble on the larger end of a glass tube in the form of a letter U, and partially filled with water; the contractile force of the bubble, transmitted through the enclosed air, forced down the water in the larger leg of the tube, and caused it to rise in the smaller. The difference of level observed by means of a microscope, gave the force in grains per square inch, derived from the known pressure of a given height of water. The thickness of the film of soap-water which formed the envelope of the bubble, was estimated as before, by the color exhibited just before bursting. The results of these experiments agree with those of weighing the bubble, in giving a great intensity to the molecular attraction of the liquid; equal at least to several hundred pounds to the square inch. Several other methods were employed to measure the tenacity of the film, the general results of which were the same: the numerical details of these are reserved, however, until the experiments can be repeated with a more delicate balance.

"The comparative cohesion of pure water and soap-water was determined by the weight necessary to detach the same plate from each; and in all cases the pure water was found to exhibit nearly double the tenacity of the soap-water. The want of permanency in the bubble of pure water is therefore not due to feeble attraction, but to the perfect mobility of the molecules, which causes the equilibrium, as in the case of the arch, without friction of parts, to be destroyed by the slightest extraneous force."

(89.) *Illustrations of the foregoing principles.*—Great tenacity of a

film of soap-water shown by the load of cotton which it will support.

The molecular attraction of soap-water shown to be less than that of pure water. Effect of salt in the water.

Explanation of the different consistencies of bodies, from perfect rigidity to perfect liquidity. Steel at one extremity of the scale and alcohol or ether at the other.

Difference of the tenacity of sealing wax in the cold and heated state.

Phenomena exhibited in pulling apart rods of metal of different degrees of rigidity.

(90.) Explanation of the development of the increase of the contractile force by curving the surface.

The molecules, on account of the curvature, are placed in a position more favorable to the action of the attracting force.

The contractile force increases directly as the curvature, and the resultant is in the direction of the radius of the circle of curvature. Explanation of this, by means of a diagram.

(91.) *Illustrations of the effect of the contractile force.*

Small bubble made to expand a large one.

Apparent elasticity of a bubble.

Phenomenon of the breaking of a cylindrical bubble.

Water poured through a bubble.

Method of forming concentric bubbles.

Form of a drop of water. Without weight it would be perfectly spherical. Cause of the incurvature of the neck of a pendent drop.

Explanation of the weight required to flatten a globule of mercury —why two drops of mercury rush together.

Explanation of the apparent elasticity of a drop of water rebounding from the surface of a solid.

Mercury sustained in a cup of wire gauze. Also water supported in the same manner.

Effect of wetting the under surface.

Fine needles made to float on the surface of water.

Feet of insects which walk on the water; sink when the feet are wet with alcohol.

In all these cases a curvature of the surface is produced which develops the contractile force.

Capillary Attraction.

(92.) Under this head is classed a set of phenomena belonging to molecular action, among which the ascent of liquids in capillary tubes is the most conspicuous, and hence the name.

When a plate of glass is plunged vertically into a vessel of water the liquid rises along the surface and covers it to an indefinite height with an exceedingly thin film. On the surface of this film another film rises, and so on until the weight of the accumulated water becomes equal to the elevating force.

(93.) The thickness of the glass does not affect the result, hence the force is limited in its action to insensible distances.

If these effects are due to adhesion and cohesion, it is evident that the first film of water is supported by the attraction of the glass—that the second coheres to the first, and the third to the second, and so on. See model and drawing.

The quantity of water thus supported by one side of a plate is equal to about $2\frac{1}{2}$ grains, (or the weight of the hundreth part of a cubic inch of water,) for each linear inch along the glass, parallel to the surface of the liquid in the vessel.

(94.) When an amalgamated plate of copper is plunged into mercury, the quantity of the metal supported above the general level and estimated in the same way is about 17 grains.

(95.) The following equation expresses the equilibrium of the forces which sustain the *first* film. In this q represents the attraction of the liquid for the solid, p that of the liquid for itself, and w the weight of the film:

$$2q - p = w. \qquad (6.)$$

Proof of this—according to the method of La Place. We see from this equation that if the attraction of the liquid for the solid is more than *half* as great as that of the liquid for itself, an elevation will be produced along the surface—hence a film of water will be elevated along a surface of ice, and a second film of water along the surface of the water of the first film, and so on. In this case

$$2p - p = w, \text{ or } p = w.$$

If the attraction of the liquid for the solid be less than half of that of the liquid for itself, then the left hand side of the equation becomes negative, and a depression will be indicated.

Example—plate of glass plunged into dry mercury.

(96.) Suppose next that two plates held parallel and opposite each other be placed in the water, the weight of liquid supported will now be double. If the plates be brought nearer, the water will rise between them, so that the weight supported may still be the same; hence the height of the liquid will be inversely as the distance of the plates.

Let the interval between the plates be the $\frac{1}{100}$th of an inch, then, since each linear inch of each plate will support $2\frac{1}{2}$ grains or the hundredth part of a cubic inch of water, therefore the liquid will stand at the height of two inches. If the plates be $\frac{1}{300}$ of an inch apart, the elevation will be 6 inches—or, if d be the distance of the plates, and h the height, then

$$h = \frac{1}{50d} \qquad (7.)$$

(97.) Next let four narrow plates be joined at their edges so as to form a prism, of which the transverse section is a square, and let this be placed in water—then the liquid, being supported on four sides instead of two, will rise to *twice* the height. Also because the circumference of a circle is to its area as the periphery of a circumscribed square is to its area, the liquid will stand at the same altitude in a

cylindrical tube as in the circumscribing prism—and hence, in the case of the tube we will have

$$h = \frac{1}{25d} \qquad (8.)$$

The results in reference to the varying distance of the plates are best exhibited by two squares of glass joined at their vertical edges and opened to an acute angle. The liquid is observed to stand at different points, at heights inversely as the distance of the plates at these points, and therefore its outline must form a hyperbole referred to its asymptotes. Proof of this.

(98.) In the case of two plates of glass plunged into mercury, the *depressing* force is also found to be constant for each linear unit of the width of the glass parallel to the horizon—consequently the depression must be inversely as the distance of the plates, and twice as great in a tube of the same diameter as the distance of the plates.

It has been found by experiment that in a glass tube of $\frac{1}{68}$th of an inch in diameter the depression is *one* inch—hence the depression in any other *glass* tube will be given by

$$d' = \frac{1}{68d}$$

and between two glass plates by (9.)

$$d'' = \frac{1}{136d}$$

(99.) Although the capillary force is constant for the same liquid, it is different for different liquids, as is shown in the following table derived from experiment:

Water	100
Solution of common salt	84
Nitric acid	75
Muriatic acid	70
Alcohol	41
Purified whale oil	37½

This table exhibits the relative heights of the different liquids in tubes of the same diameter.

(100.) In the elevation of liquids in tubes the height is the same with the same diameter, whatever may be the substance of which the tube is composed, but in the case of depression the depressing force varies with the substance of the tube as well as with the diameter. Explanation of this.

(101.) The elevation of liquids is readily explained in its general features, on the principle we have already given of the adhesion of the liquid to the solid and the cohesion of the liquid to itself; but to explain the depression and a number of other facts connected with the subject require something more.

Various hypotheses have been advanced for the explanation of capillary phenomena, the most important of which are those of Jurin, Clairaut, Robison, Lesley, La Place, Young and Poisson. Almost every one of these may be considered as an improvement on the preceding, or a closer approximation to truth.

(102.) According to the improved hypothesis, or theory as it may now be called, of Poisson and Young, the phenomena are not only due to the attractions of the liquid and solid, but also to the contractile force existing in the free surface of every liquid, and which is increased or diminished in a given direction by a convexity or concavity of this surface.

To apply these principles to the phenomena of capillarity, let us first suppose two plates plunged perpendicularly into a liquid on which they have no action; then the liquid will be divided from itself, the contractile force will be developed along the free surface contiguous to each plate, the liquid will be drawn down until the hydrostatic pressure balances the contractile force, and we will have the following as the equation of equilibrium:

$$2c = w. \qquad (10.)$$

(103.) Next let the plates have an attraction for the liquid, but not as great as that of the liquid for itself, as in the example of glass and mercury.

The liquid in this case will not be entirely separated from the glass so as to produce a perfectly free surface, but will be pressed against it by the attraction; the contractile force will, therefore, be partially neutralized, and the depression consequently be less.

If d be the diminution in the contractile force in consequence of the attraction of the glass, then

$$2\,(c - d) = w. \qquad (11.)$$

Since c and d must remain the same with the same liquid and solid, w will also be constant; and hence the depression will be inversely as the distance of the plates, or the diameter of the tube.

Also, with the same liquid and solid, the angle of *contact* will remain constant, and the curvature of the upper surface will be inversely as the distance of the plates, and therefore the curvature may be taken, as it has been by La Place, as the measure of the capillary force.

(104.) If the attraction of the liquid for the solid be greater than for itself, then the film in contact will be drawn up, the surface between the plates will be rendered concave—a superficial tension will be developed along the curved surface and the liquid will rise until the tension due to the curvature balances the weight of the column.

The curvature in this case will also be inversely as the distance of the plates, since the angle of contact remains the same—hence so long as the exterior surface remains unchanged in form, the elevation will be inversely as the distance of the plates.

But if the surface without the tube be rendered either concave or convex, a contractile force will be developed which will tend to elevate or depress the column.

(105.) The equilibrium of the capillary forces may be expressed by the following general equation in which Z is the elevation or depression, T a co-efficient for each fluid and solid, R and R′ the radii of curvature

$$Z=T\left(\frac{1}{R}+\frac{1}{R'}\right) \qquad (12.)$$

(106.) Illustrations of the effects of curvature on the length of the column—the exterior surface of a liquid rendered concave, the column in the tube depressed—convex the reverse. The surface of the exterior liquid made concave, the height of the column in the tube diminished—convex increased.

Column supported in a tube with a drop of liquid at the end is depressed by touching the drop to a surface of liquid—effect of convex and concave surface exhibited by means of a small inverted syphon.

Movement of a drop of water in a conical glass tube—also between two glass plates.

Reverse movement of a drop of mercury.

Apparent attraction of two plates with film of water interposed. Effect of double curvature of the liquid surface.

A small glass rod in a large capillary tube filled with water, does not fall out but rebounds from the lower surface of the liquid.

Illustration of Capillary Phenomena.—Surface crystallization—water imbibed by sponge, the pores require to be previously wetted by pressure. Water drawn up into sand. Oil supplied by the wick—bundle of fine wire may be used for the same purpose. Method of oiling the axles of the locomotive. Marble absorbs oil but not water; the oil extracted by clay.

Water passed through filtering paper by capillary force, collects on the lower side into drops, by cohesion, falls by gravity. Different liquids separated by previously wetting the filter with one of them. Cloth rendered air-tight by water.

The dimensions of bodies are often changed by imbibing water. The untwisting of catgut, and of the beard of the wild oat, the shortening of strings and the lengthening of whalebone, all furnish *hygroscopes*, or instruments for indicating the state of moisture of the air.

The intensity of the capillary action is exceedingly great; water is drawn into wood with such force as to split rocks. A large weight raised by the contraction of a rope in the direction of its length, while it is increasing in diameter. The same force is not exerted when oil is absorbed. Cause of warping and splitting of furniture—use of oiling and varnishing to prevent this.

French method of saturating timber with substances for its preservation.

(107.) *Apparent attraction and repulsion of floating bodies.*—Two moistened or two smoked corks approach each other; but a moistened and a smoked cork separate. Also a moistened cork adheres to the side of a glass vessel, partially filled with water, but it moves towards the centre when the liquid is heaped on the vessel above the rim.

(108.) *Endosmose,* (from *ενδον* and *ωσμος*). The transmission of

one liquid into another through the pores of the substance which separates them. The effect is due to an *elective* capillary attraction and a subsequent mixing of the liquids. A bladder can be soaked with water, but is merely infilmed with alcohol—hence the more rapid transmission of one of these liquids through this membrane than the other.

Same result produced with other liquids, provided they have different degrees of attraction for the membrane, and a strong tendency to mix with each other.

The endosmometer exhibited.

(109.) The endosmose, (or flowing in) of the exterior liquid is generally accompanied by the exosmose (*εξω* and *ωσμος* or flowing out) of the interior liquid, but to a much less extent, the difference depending upon the greater or less attraction for the interposed substance.

Modifications of this action perform an important part in many of the operations of vegetable and animal life.

Method of strengthening wine by a bladder over the mouth of the bottle.

Endosmose probably takes place to a slight degree, between gases in their transfusion through porous substances, although most of the phenomena of this kind can be explained on the principle of a difference in weight, and Dalton's law of diffusion. It is, however, certain that capillary attraction does take place in an eminent degree between solids and gases. Newly burnt charcoal absorbs 90 times its bulk of ammoniacal gas, 35 times of carbonic acid, and 9.2 times of oxygen. The gas in some of these cases must be condensed by the attraction into a liquid.

(110.) *Chemical Attraction,*

Or, as it is generally called, chemical affinity, is the highest degree of heterogeneous attraction—it takes place between the component molecules of different kinds of matter, and produces other matter of entirely different qualities.

The peculiarities of this attraction are as follows: 1. It is *elective;* the intensity of action is not the same between all bodies, so that one substance may displace another in a compound by its superior attraction for the other ingredient. 2. It is *definite;* the same quantity of any substance has the same saturating power in reference to all matter with which it combines. 3. It *determines the peculiar properties* of the compound. In these peculiarities it differs materially from gravitation, the intensity of which is the same for all matter, and does not admit of saturation, the attraction of *a* for *b* does not interfere with the attraction of *a* for *c*.

The operation of this attraction is intimately connected with the electricity, and will be referred to again under the head of galvanism. It forms an essential part of chemistry, and its peculiarities are fully described and illustrated in that branch of science.

Elasticity.

(111.) By this term we understand that property of bodies by which they return to their original form and dimensions when an extraneous force, to which they have been submitted, is withdrawn.

The term elasticity is also used to express the force with which any body resists a change of density or of form. In this sense the elasticity of water is greater than that of air. The ambiguity may be avoided by employing the expression *elastic force* for the latter.

All bodies in mechanics are sometimes divided into two classes, elastic and non-elastic, and sometimes into perfectly and imperfectly elastic. Examples.

But in reality all bodies are perfectly elastic within certain limits which differ widely in different bodies. The late experiments presented to the British Association do not, I think, establish the contrary.

(112.) *Elasticity of gases.*—The molecules of gases being entirely within the region of repulsion, they tend constantly to separate from each other, and are only confined within a given volume by the sides of the vessel which contains them. The range of elasticity in these is much greater than in liquids and solids.

The laws of Boyle and Mariotte.

1. *The elastic force and density of a gas are directly as the pressure.*
2. *The bulk of a gas is inversely as the pressure.*

(113.) Experimental proof of these laws. Precautions to be observed. The second has been found to hold true in the case of common air, to the extent of a pressure of twenty-four atmospheres.

It is probable, however, that these laws are true for all gases only within certain limits; several gases have been condensed into liquids, and analogy would lead us to infer that all of them might be reduced to the same state if sufficient pressure could be applied. In those which have been liquefied, the laws fail as the point of liquefaction is approached. On the other hand, if the gases were sufficiently expanded, we cannot doubt that the molecular repulsion would finally pass into the attraction of gravitation. These facts are in accordance with the theory of Boscovich.

Experiment to illustrate this. Several gases submitted at the same time to the same intense pressure; condensation finally becomes unequal.

To account for the laws of elasticity, we may suppose, with Newton, that the force between the atoms is inversely as their distances; but if we adopt this hypothesis we are obliged to admit that the action of each atom does not extend beyond the atoms nearest to it, however greatly they may be crowded together. The explanation of Dr. Robison is more probable; according to this, the repulsion remains the same for a certain range of distance, and the law of elasticity is the result of the greater number of atoms forced into the same space; the repulsion being in proportion to the number of the repelling centres.

Illustration of this by a diagram of atoms, and also by the curve of Boscovich.

(114.) *Elasticity of liquids.*—The range of elasticity in these bodies is exceedingly small when compared with that of gases, but the elastic force is much greater.

The diminution of bulk is found by experiment to be proportional to the pressure. If B represent the bulk under a given pressure, P, and other pressures be added in succession, then the corresponding pressures and bulks will be as follows:

$P+p$ . . .	$B-b$
$P+2p$ . . .	$B-2b$
$P+3p$ . . .	$B-3b$
$P+np$ . . .	$B-nb$

It is evident that this law must have a limit; otherwise the matter may be annihilated by sufficient pressure.

For a long time it was supposed that liquids were incompressible and inelastic. Canton, in 1761, was the first who compressed water; since then the subject has been studied and extended by Perkins, Œrsted and others.

(115.) Perkins's apparatus;—an iron bottle with a piston filled to the neck; pressure produced by sinking this into the deep sea.

Œrsted's apparatus exhibited. It consists principally of three parts: 1st. An exterior vessel which takes the place of the deep sea, and in which the pressure is produced by a screw and piston. 2d. Of an inner vessel containing the liquid to be compressed called a Piezometer, (πιεζω and μετρον.) 3d. Of an inverted glass tube filled with air, the diminution of which in bulk indicates the compressing force.

Method of graduating the stem of the piezometer—each division indicates the 2 millionths of the whole bulk.

Self-registering piezometer for pressures which would break the exterior glass vessel.

Discussion as to the variation in the capacity of the piezometer. According to Poisson it becomes smaller—according to Œrsted, larger. The opinion of the former is correct.

The following is the compressibility of liquids, according to the experiments of Colladon and Sturm of Geneva, expressed in millionths of the primitive bulk, for an additional pressure of our atmosphere:

Mercury, ...	3.38
Sulphuric acid, ...	30.35
Water not freed from air, . . .	47.85
Water freed from air, ...	49.65
Alcohol, (1st atmos.)	94.95
do., (5th do.)	91.89
Sulphuric ether, (1st atmos.) . . .	131.35
do. do. (24th do.) . . .	120.45

The greater the density the greater the repulsive force. Change of temperature affects the compressibility.

(116.) *The Elasticity of Solids.*—This may be considered under three heads: viz., the elasticity of *compression and dilatation*, of bending, and of *torsion*.

Elasticity of Compression, &c.—In masses of solids, compressed on

all sides, the law of diminution is the same as that which has been given for liquids. The degree of compressibility may also be determined by the use of Œrsted's apparatus. Explanation of this.

In rods and wires drawn, in the direction of their axes, the elongation within certain limits is just in proportion to the force applied. When the force is removed the body resumes its ordinary dimensions.

With a force which exceeds the limits of elasticity, the position of the molecules is permanently changed, and the body is said *to take a set*. After this the molecules will oscillate around their new position of equilibrium and the body will again be perfectly elastic, within, however, a different limit.

The elastic force of wires of different substances may be found by the use of *Gravesand's apparatus*. Explanation of this.

In stretching a rod or a wire the diameter is diminished one-fourth of the extension in length, and therefore the whole volume is increased.

When the stretching force approaches the limit of cohesion, the dilatation becomes very irregular.

On the principle of *taking a set* depends the malleability and ductility of bodies, or the properties of being extended and modeled by the hammer, and of being drawn out into wire.

Illustrations. Gold is one of the most malleable substances; platinum one of the most ductile. A flat sheet of copper may be beaten into a hollow globular vessel, with a small opening at the top, without seam or joint. The rolling, coining, and stamping of metal depend on the same principle. Frequent annealing is necessary during the process.

(117.) *Elasticity of Bending.*—In the case of plates and rods *the force of bending* is just in proportion to the degree of bending, and within small limits the body in this respect is perfectly elastic. This fact was discovered by Dr. Hooke in 1660, and expressed by the phrase

"*Ut tensio sic vis.*"

Experimental illustrations of this law. Weights suspended from the middle, and also from the end of a flexible bar. Elongation of a spiral spring.

It follows from this law that all the vibrations of a thin plate fastened at one end are *isochronous*. Proof of this—the force increases in proportion to the distance to be passed over.

It was this relation that suggested to Dr. Hooke the application of the hair-spring to a watch. On the same principle also depends the operation of the extemporary weighing machine, the spring balance, and the dynamometer.

Effect of loading the spring; the time of vibration must be as the weight.

In bending a rod the molecules on the concave side are pressed nearer together, while those on the opposite side are drawn further apart; between these a line must exist called the neutral axis, in which the distance of the molecules is unchanged. These inferences from the molecular hypothesis shown to be true by means of polarized

light, and the bending of a rectangular prism of glass. Also illustrated by a diagram.

(118.) *Elasticity of Torsion.*—Apparatus and experiments of Coulomb exhibited. Double horizontal pendulum suspended by a fine wire.

The force of torsion is just in proportion to the angle of torsion, or again we have *ut tensio sic vis.*

All the vibrations are therefore in this case also performed in the same time, whatever be the amplitude.

Because the force of torsion varies as the angle of torsion, the vibrations of a torsion pendulum are governed by the same laws as those of the cycloidal pendulum; hence we shall have by mechanics

$$T = \pi \sqrt{\frac{L}{f}}$$

In this expression, in which T is the time, f the elastic force, and L the length of the radius of the double pendulum, the diameter of the wire and the weight which stretches the wire are each supposed to be equal to unity.

If the weight be increased to W, then the velocity or the measure of the force will evidently be diminished in the same ratio, and instead of f we shall have $\frac{f}{W}$. Hence by substitution,

$$T = \pi \sqrt{\frac{LW}{f}} \quad or$$

1. *The time of vibration is as the square root of the weight which stretches the wire.*

If the length of the wire be increased to l, then for a given angle of torsion the molecules will be separated inversely as the length; therefore the force will be expressed by $\frac{f}{l}$, and by substitution, we shall have

$$T = \pi \sqrt{\frac{L\,l}{f}} \quad or$$

2. *The other quantities remaining the same, the time varies as the square root of the length of the wire.*

Again, if the diameter of the wire becomes r, then r^2 will represent the increased number of molecules, and since the mean distance of separation of these for a given torsion will vary as r, and also the distance from the centre to the point of application at r, it follows that the whole force will be expressed by r^4, and therefore by substituting again, we shall have

$$T = \frac{1}{r^2} \pi \sqrt{\frac{L}{f}} \quad or$$

The time varies inversely as the square of the radius of the wire, the other quantities being constant.

All these inferences are in strict accordance with the results of accurate experiments.

(119.) The application of the torsion pendulum to the measurement of small forces,—Coulomb's balance of torsion,—Cavendish's experiment of weighing the earth. The hair spring of a watch—new clock.

Torsion is a means of exhibiting the elasticity of some bodies which ordinarily appear *inelastic.* The elasticity of a lead wire may be shown by torsion; also of a rope of moistened clay.

The degree of elasticity of some solids depends on a peculiar arrangement of the molecules of the surface, called *temper.* Steel, heated to a cherry red, and then plunged into cold water, has its elastic force much increased—it becomes as hard and as brittle as glass. If it be again heated until it exhibits a blue color, and is again plunged into water, a "spring temper" is produced, or the metal assumes a much wider range of elasticity.

A tempered bar of steel is larger than one of the same weight which has been suffered to cool gradually; also on breaking the bar the temper is found to be superficial. Probable explanation of temper. The outer crust is suddenly cooled over a heated and dilated nucleus—the latter shrinks in cooling, and leaves the crust in a state of tension. Cast iron may also be tempered by the solidifying process called *chill-casting.*

Glass also possesses the property of receiving a temper. Large drops of this substance let fall into water suddenly solidify at the surface, and thus the molecules assume a state of tension analogous to that of tempered steel. Pieces of glass of this kind are called *Prince Rupert's drops;* they will bear a considerable blow on the end, but if the tail of the drop be broken, the whole explodes into a fine powder.

The molecular force developed in this explosion is astonishingly great —a thick tumbler broken by it.

The drops lose their peculiar property by being heated and gradually cooled.

The existence of a state of tension in the unannealed drop shown by polarized light.

The method of annealing glass for domestic and other uses explained.

The Chinese gong metal, called *tam-tam,* which consists of four parts of copper and one of tin, possesses the remarkable property of becoming hard and brittle by slow cooling.

(TO BE CONTINUED IN THE NEXT REPORT.)

ON ACOUSTICS

APPLIED TO PUBLIC BUILDINGS.*

BY PROFESSOR JOSEPH HENRY,

SECRETARY OF THE SMITHSONIAN INSTITUTION.

At the meeting of the American Association in 1854, I gave a verbal account of a plan of a lecture-room adopted for the Smithsonian Institution, with some remarks on acoustics as applied to apartments intended for public speaking. At that time the room was not finished, and experience had not proved the truth of the principles on which the plan had been designed. Since then the room has been employed two winters for courses of lectures to large audiences, and I believe it is the universal opinion of those who have been present, that the arrangement for seeing and hearing, considering the size of the apartment, is entirely unexceptionable. It has certainly fully answered all the expectations which were formed in regard to it previous to its construction. The origin of the plan was as follows:

Professor Bache and myself had directed our attention to the subject of acoustics as applied to buildings, and had studied the peculiarities in this respect of the hall of the House of Representatives, when the President of the United States referred to us for examination the plans proposed by Captain Meigs, of the Engineer Corps, for the rooms about to be constructed in the new wings of the Capitol. After visiting with Captain Meigs the principal halls and churches of the cities of Philadelphia, New York, and Boston, we reported favorably on the general plans proposed by him, and which were subsequently adopted. The facts which we have collected on this subject may be referred to a few well established principles of sound, which have been applied in the construction of this lecture-room. To apply them generally, however, in the construction of public halls, required a series of preliminary experiments.

In a very small apartment it is an easy matter to be heard distinctly at every point; but in a large room, unless from the first, in the original plan of the building, provision be made, on acoustic principles, for a suitable form, it will be difficult, and, indeed, in most cases impossible, to produce the desired effect. The same remark may be applied to lighting, heating, and ventilation, and to all the special purposes to which a particular building is to be applied. I beg, therefore, to make some preliminary remarks on the architecture

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* Read before the American Association for the Advancement of Science, in August, 1856.

of buildings bearing upon this point, which, though they may not meet with universal acceptance, will, I trust, commend themselves to the common sense of the public in general.

In the erection of a building, the uses to which it is to be applied should be clearly understood and provision definitely made in the original plan for every desired object.

Modern architecture is not, like painting or sculpture, a fine art *par excellence;* the object of these latter is to produce a moral emotion, to awaken the feelings of the sublime and the beautiful, and we egregiously err when we apply their productions to a merely utilitarian purpose. To make a fire screen of Rubens's Madonna, or a candelabrum of the statue of the Apollo Belvidere, would be to debase these exquisite productions of genius, and do violence to the feelings of the cultivated lover of art. Modern buildings are made for other purposes than artistic effect, and in them the æsthetical must be subordinate to the useful, though the two may coexist, and an intellectual pleasure be derived from a sense of adaptation and fitness, combined with a perception of harmony of parts, and the beauty of detail.

The buildings of a country and an age should be an ethnological expression of the wants, habits, arts, and sentiment of the time in which they were erected. Those of Egypt, Greece, and Rome were intended, at least in part, to transmit to posterity, without the art of printing, an idea of the character of the periods in which they were erected. It was by their monuments that these nations sought to convey an idea of their religious and political sentiments to future ages.

The Greek architect was untrammelled by any condition of utility. Architecture was with him in reality a fine art. The temple was formed to gratify the tutelar deity. Its minutest parts were exquisitely finished, since nothing but perfection on all sides, and in the smallest particulars, could satisfy an all-seeing and critical eye. It was intended for external worship, and not for internal use. It was without windows, entirely open to the sky, or, if closed with a roof, the light was merely admitted through a large door. There were no arrangements for heating or ventilation. The uses, therefore, to which, in modern times, buildings of this kind can be applied, are exceedingly few; and though they were objects of great beauty, and fully realized the intention of the architect by whom they were constructed, yet they cannot be copied in our day without violating the principles which should govern architectural adaptation.

Every vestige of ancient architecture which now remains on the face of the earth should be preserved with religious care; but to servilely copy these, and to attempt to apply them to the uses of our day, is as preposterous as to endeavor to harmonize the refinement and civilization of the present age with the superstition and barbarity of the times of the Pharaohs. It is only when a building expresses the dominant sentiment of an age, when a perfect adaptation to its use is joined to harmony of proportions and an outward expression of its character, that is entitled to our admiration. It has been aptly said, that it is one thing to adopt a particular style of architecture, but a very different one to *adapt* it to the purpose required.

Architecture should change not only with the character of the peo-

ple, and in some cases with the climate, but also with the material to be employed in construction. The use of iron and of glass requires a modification of style as much as that which sprung from the rocks of Egypt, the masses of marble with which the lintels of the Grecian temples were formed, or the introduction of brick by the Romans.

The great tenacity of iron, and its power of resistance to crushing, should suggest for it, as a building material, a far more slender and apparently lighter arrangement of parts. An entire building of iron, fashioned in imitation of stone, might be erected at small expense of invention on the part of the architect, but would do little credit to his truthfulness or originality. The same may be said of our modern pasteboard edifices, in which, with their battlements, towers, pinnacles, "fretted roofs and long drawn aisles," cheap and transient magnificence is produced by painted wood or decorated plaster. I must not, however, indulge in remarks of this kind, but must curb my feelings on the subject, since I speak from peculiar experience.

But to return to the subject of acoustics as applied to apartments intended for public speaking. While sound, in connexion with its analogies to light, and in its abstract principles, has been investigated within the last fifty years with a rich harvest of results, few attempts have been successfully made to apply these principles to practical purposes. Though we may have a clear conception of the simple operation of a law of nature, yet when the conditions are varied, and the actions multiplied, the results frequently transcend our powers of logic, and we are obliged to appeal to experiment and observation to assist in deducing new consequences, as well as to verify those which have been arrived at by mathematical deduction. Furthermore, though we may know the manner in which a cause acts to produce a given effect, yet in all cases we are obliged to resort to actual experiment to ascertain the measure of effect under given conditions.

The science of acoustics as applied to buildings, perhaps more than any other, requires this union of scientific principles with experimental deductions. While, on the one hand, the application of simple deductions from the established principles of acoustics would be unsafe from a want of knowledge of the constants which enter into our formulæ, on the other hand, empirical data alone are, in this case, entirely at fault, and of this any person may be convinced who will examine the several works written on acoustics by those who are deemed practical men.

Sound is a motion of matter capable of affecting the ear with a sensation peculiar to that organ. It is not in all cases simply a motion of the air, for there are many sounds in which the air is not concerned; for example, the impulses which are conveyed along a rod of wood from a tuning-fork to the teeth. When a sound is produced by a single impulse, or an approximation to a single impulse, it is called a noise; when by a series of impulses, a continued sound, &c.; if the impulses are equal in duration among themselves, a musical sound. This has been illustrated by a quill striking against the teeth of a wheel in motion. A single impulse from one tooth is a noise, from a series of teeth in succession a continued sound; and if all the teeth are at equal distances, and the velocity of the wheel is uniform, then

a musical note is the result. Each of these sounds is produced by the human voice, though they apparently run into each other. Usually, however, in speaking, a series of irregular sounds of short duration are emitted,—each syllable of a word constitutes a separate sound of appreciable duration, and each compound word and sentence an assemblage of such sounds. It is astonishing that, in listening to a discourse, the ear can receive so many impressions in the space of a second, and that the mind can take cognizance of and compare them.

That a certain force of impulse, and a certain time for its continuance, are necessary to produce an audible impression on the ear, is evident; but it may be doubted whether the impression of a sound on this organ is retained appreciably longer than the continuance of the impulse itself; except in cases of loud sounds. If this were the case, it is difficult to conceive why articulated discourse, which so pre-eminently distinguishes man from the lower animals, should not fill the ear with a monotonous hum; but whether the ear continues to vibrate, or whether the impression remains a certain time on the sensorium, it is certain that no sound is ever entirely instantaneous, or the result of a single impression, particularly in enclosed spaces. The impulse is not only communicated to the ear, but to all bodies around, which, in turn, themselves become centres of reflected impulses. Every impulse must give rise to a forward, and afterwards to a return, or backward, motion of the atom.

Sound from a single explosion in air, equally elastic on all sides, tends to expand equally in every direction; but when the impulse is given to the air in a single direction, though an expansion takes place on all sides, yet it is much more intense in the line of the impulse. For example, the impulse of a single explosion, like that of the detonation of a bubble of oxygen and hydrogen, is propagated equally in all directions, while the discharge of a cannon, though heard on every side, is much louder in the direction of the axis; so also a person speaking is heard much more distinctly directly in front than at an equal distance behind. Many experiments have been made on this point, and I may mention those repeated in the open space in front of the Smithsonian Institution. In a circle, 100 feet in diameter, the speaker in the centre, and the hearer in succession at different points of the circumference, the voice was heard most distinctly directly in front, gradually less so on either side, until, in the rear, it was scarcely audible. The ratio of distance for distinct hearing directly in front, on the sides, and in the rear, was about as 100, 75, and 30. These numbers may serve to determine the form in which an audience should be arranged in an open field, in order that those on the periphery of the space may all have a like favorable opportunity of hearing, though it should not be recomended as the interior form of an apartment, in which a reflecting wall would be behind the speaker.

The impulse producing sound requires time for its propagation, and this depends upon the intensity of repulsion between the atoms, and, secondly, on the specific gravity of the matter itself. If the medium were entirely rigid, sound would be propagated instantaneously; the weaker the repulsion between the atoms, the greater will be the time required to transmit the motion from one to the other; and the

heavier the atoms, the greater will be the time required for the action of a given force to produce in them a given amount of motion. Sound also, in meeting an object, is reflected in accordance with the law of light, making the angle of incidence equal to the angle of reflection. The tendency, however, to divergency in a single beam of sound appears to be much greater than in the case of light. The law, nevertheless, appears to be definitely followed in the case of all beams that are reflected in a direction near the perpendicular. It is on the law of propagation and reflection of sound that the philosophy of the echo depends. Knowing the velocity of sound, it is an easy matter to calculate the interval of time which must elapse between the original impulse and the return of the echo. Sound moves at the rate of 1,125 feet in a second, at the temperature of 60°.*

If, therefore, we stand at half this distance before a wall, the echo will return to us in one second. It is, however, a fact known from general experience, that no echo is perceptible from a near wall, though in all cases one must be sent back to the ear. The reason of this is, that the ear cannot distinguish the difference between similar sounds, as, for example, that from the original impulse and its reflection, if they follow each other at less than a given interval, which can only be determined by actual experiment; and as this is an important element in the construction of buildings, the attempt was made to determine it with some considerable degree of accuracy. For this purpose the observer was placed immediately in front of the wall of the west end of the Smithsonian building, at a distance of 100 feet; the hands were then clapped together. A distinct echo was perceived; the difference between the time of the passage of the impulse from the hand to the ear, and that from the hand to the wall and back to the ear, was sufficiently great to produce two entirely distinct impressions. The observer then gradually approached the building, until no echo or perceptible prolongation of the sound was observed. By accurately measuring this distance, and doubling it, we find the interval of space within which two sounds may follow each other without appearing separately. But if two rays of sound reach the ear after having passed through distances the difference between which is greater than this, they produce the effect of separate sounds. This distance we have called the *limit of perceptibility* in terms of space. If we convert this distance into the velocity of sound, we ascertain the limit of perceptibility in time.

In the experiment first made with the wall, a source of error was discovered in the fact that a portion of the sound returned was reflected from the cornice under the eaves, and as this was at a greater distance than the part of the wall immediately perpendicular to the observer, the moment of the cessation of the echo was less distinct. In subsequent experiments with a louder noise, the reflection was observed from a perpendicular surface of about 12 feet square, and from this more definite results were obtained. The limit of the distance in this case was about 30 feet, varying slightly, perhaps, with the intensity

* From the average of all the experiments, according to Sir John Herschel, the velocity of sound is 1,090 feet at the temperature of 32°, and this is increased 1.14 feet for every degree of temperature of Fahrenheit's scale.

of the sound and the acuteness of different ears. This will give about the sixteenth part of a second as the limit of time necessary for the ear to separately distinguish two similar sounds. From this experiment we learn that the reflected sound may tend to strengthen the impression, or to confuse it, according as the difference of time between the two impressions is greater or less than the limit of perceptibility. An application of the same principle gives us the explanation of some phenomena of sound which have been considered mysterious. Thus, in the reflection of an impulse from the edge of a forest of trees, each leaf properly situated within a range of 30 feet of the front plane of reflection will conspire to produce a distinct echo, and these would form the principal part of the reflecting surfaces of a dense forest, for the remainder would be screened; and being at a greater distance, any ray which might come from them would serve to produce merely a low continuation of the sound.

On the same principle, we may at once assert that the panelling of a room, or even the introduction of reflecting surfaces at different distances, will not prevent the echo, provided they are in parallel planes, and situated, relatively to each other, within the limit of perceptibility.

Important advantage may be taken of the principle of reflection of sound by the proper arrangement of the reflecting surfaces behind the speaker. We frequently see in churches, as if to diminish the effect of the voice of the preacher, a mass of drapery placed directly in the rear of the pulpit. However important this may be in an æsthetical point of view, it is certainly at variance with correct acoustic arrangements—the great object of which should be to husband every articulation of the voice, and to transmit it unmingled with other impulses, and with as little loss as possible, to the ears of the audience.

Another effect of the transmission and reflection of sound is that which is called reverberation, which consists of a prolonged musical sound, and is much more frequently the cause of indistinctness of perception of the articulations of the speaker than the simple echo.

Reverberation is produced by the repeated reflection of a sound from the walls of the apartment. If, for example, a single detonation takes place in the middle of a long hall with naked and perpendicular walls, an impulse will pass in each direction, will be reflected from the walls, cross each other again at the point of origin, be again reflected, and so on until the original impulse is entirely absorbed by the solid materials which confine it. The impression will be retained upon the ear during the interval of the transmission past it of two successive waves, and thus a continued sound will be kept up, particularly if the walls of any part of the room are within 30 feet of the ear. If a series of impulses, such as that produced by the rapid snaps of a quill against the teeth of a wheel, be made in unison with the echoes, a continued musical sound will be the result. Suppose the wheel to be turned with such velocity as to cause a snap at the very instant the return echo passes the point at which the apparatus is placed, the second sound will combine with the first, and thus a loud and sustained vibration will be produced. It will be evident from this that every room has a key-note, and that, to an instrument of the proper pitch, it will resound with great force. It must be apparent, also, that the

continuance of a single sound, and the tendency to confusion in distinct perception will depend on several conditions; first, on the size of the apartment; secondly, on the strength of the sound or the intensity of the impulse; thirdly, on the position of the reflecting surfaces; and fourthly, on the nature of the material of the reflecting surfaces.

In regard to the first of these, the larger the room, the longer time will be required for the impulse along the axis to reach the wall; and if we suppose that at each collision a portion of the original force is absorbed, it will require double the time to totally extinguish it in a room of double the size, because, the velocity of sound being the same, the number of collisions in a given time will be inversely as the distance through which the sound has to travel.

Again, that it must depend upon the loudness of the sound, or the intensity of the impulse, must be evident, when we consider that the cessation of the reflections is due to the absorption of the walls, or to irregular reflection, and that, consequently, the greater the amount of original disturbance, the longer will be the time required for its complete extinction. This principle was abundantly shown by our observations on different rooms.

Thirdly, the continuance of the resonance will depend upon the position of the reflecting surfaces. If these are not parallel to each other, but oblique, so as to reflect the sound, not to the opposite, but to the adjacent wall, without passing through the longer axis of the room, it will evidently be sooner absorbed. Any obstacle, also, which may tend to break up the wave, and interfere with the reflection through the axis of the room, will serve to lessen the resonance of the apartment. Hence, though the panelling, the ceiling, and the introduction of a variety of oblique surfaces, may not prevent an isolated echo, provided the distance be sufficiently great, and the sound sufficiently loud, yet that they do have an important effect in stopping the resonance is evident from theory and experiment. In a room fifty feet square, in which the resonance of a single intense sound continued six seconds, when cases and other objects were placed around the wall, its continuance was reduced to two seconds.

Fourthly, the duration of the resonance will depend upon the nature of the material of the wall. A reflection always takes place at the surface of a new medium, and the amount of this will depend upon the elastic force or power to resist compression and the density of the new medium. For example, a wall of nitrogen, if such could be found, would transmit nearly the whole of a wave of sound in air, and reflect but a very small portion; a partition of tissue-paper would produce nearly the same effect. A polished wall of steel, however, of sufficient thickness to prevent yielding, would reflect, for practical purposes, all the impulses through the air which might fall upon it. The rebound of the wave is caused, not by the oscillation of the wall, but by the elasticity and mobility of the air. The striking of a single ray of sound against a yielding board would probably increase the loudness of the reverberation, but not its continuance. On this point a series of experiments were made by the use of the tuning-fork. In this instrument, the motion of the foot and of the two prongs gives a sonorous vibration to the air, which, if received upon another tuning-fork

of precisely the same size and form, would reproduce the same vibrations.

It is a fact well established by observation, that when two bodies are in perfect unison, and separated from each other by a space filled with air, vibrations of the one will be transmitted to the other. From this consideration it is probable that relatively the same effect ought to be produced in transmitting immediately the vibration of a tuning-fork to a reflecting body, as to duration and intensity, as in the case of transmission through air. This conclusion is strengthened by floating a flat piece of wood on water in a vessel standing upon a sounding-board; placing a tuning-fork on the wood, the vibrations will be transmitted to the board through the water, and sounds will be produced of the same character as those emitted when the tuning-fork is placed directly upon the board.

A tuning-fork suspended from a fine cambric thread, and vibrated in air, was found, from the mean of a number of experiments, to continue in motion 252 seconds. In this experiment, had the tuning-fork been in a perfect vacuum, suspended without the use of a string, and, further, had there been no ethereal medium, the agitation of which would give rise to light, heat, electricity, or some other form of ethereal motion, the fork would have continued its vibration forever.

The fork was next placed upon a large, thin pine board, the top of a table. A loud sound in this case was produced, which continued less than *ten* seconds. The whole table as a system was thrown into motion, and the sound produced was as loud on the under side as on the upper side. Had the tuning-fork been placed against a partition of this material, a loud sound would have been heard in the adjoining room; and this was proved by sounding the tuning-fork against a door leading into a closed closet. The sound within was apparently as loud as that without.

The rapid decay of sound in this case was produced by so great an amount of the motive power of the fork being communicated to a large mass of wood. The increased sound was due to the increased surface. In other words, the shortness of duration was compensated for by the greater intensity of effect produced.

The tuning-fork was next placed upon a circular slab of marble, about three feet in diameter and three quarters of an inch thick. The sound emitted was feeble, and the undulations continued *one hundred and fifteen* seconds, as deduced from the mean of six experiments.

In all these experiments, except the one in a vacuum, the time of the cessation of the motion of the tuning-fork was determined by bringing the mouth of a resounding cavity near the end of the fork; this cavity, having previously been adjusted to unison with the vibrations of the fork, gave an audible sound when none could be heard by the unaided ear.

The tuning-fork was next placed upon a cube of India rubber, and this upon the marble slab. The sound emitted by this arrangement was scarcely greater than in the case of the tuning-fork suspended from the cambric thread, and from the analogy of the previous experiments we might at first thought suppose the time of duration would be great; but this was not the case. The vibrations continued

only about forty seconds. The question may here be asked, what became of the impulses lost by the tuning-fork? They were neither transmitted through the India rubber nor given off to the air in the form of sound, but were probably expended in producing a change in the matter of the India-rubber, or were converted into heat, or both. Though the inquiry did not fall strictly within the line of this series of investigations, yet it was of so interesting a character in a physical point of view to determine whether heat was actually produced, that the following experiment was made:

A cylindrical piece of India rubber, about an inch and a quarter in diameter was placed in a tubulated bottle, with two openings, one near the bottom and the other at the top. A stuffing-box was attached to the upper, through which a metallic stem, with a circular foot to press upon the India rubber, was made to pass air-tight. The lower tubular was closed with a cork, in a perforation of which a fine glass tube was cemented. A small quantity of red ink was placed in the tube to serve as an index. The whole arrangement thus formed a kind of air-thermometer, which would indicate a certain amount of change of temperature in the enclosed air. On the top of the stem, the tuning-fork was screwed, and consequently its vibrations were transmitted to the rubber within the bottle. The glass was surrounded with several coatings of flannel to prevent the influence of external temperature. The tuning-fork was then sounded, and the vibrations were kept up for some time. No reliable indications of an increase of temperature were observed. A more delicate method of making the experiment next suggested itself. The tube containing the drop of red ink, with its cork was removed, and the point of a compound wire formed of copper and iron was thrust into the substance of the rubber, while the other ends of the wire were connected with a delicate galvanometer. The needle was suffered to come to rest, the tuning-fork was then vibrated, and its impulses transmitted to the rubber. A very perceptible increase of temperature was the result. The needle moved through an arc of from one to two and a half degrees. The experiment was varied, and many times repeated; the motions of the needle were always in the same direction, namely, in that which was produced when the point of the compound wire was heated by momentary contact with the fingers. The amount of heat generated in this way is, however, small, and indeed, in all cases in which it is generated by mechanical means, the amount envolved appears very small in comparison with the labor expended in producing it. Jule has shown that the mechanical energy generated in a pound weight, by falling through a space of seven hundred and fifty feet, elevates the temperature of a pound of water one degree.

It is evident that an object like India rubber actually destroys a portion of the sound, and hence, in cases in which entire non-conduction is required, this substance can probably be employed with perfect success.

The tuning-fork was next pressed upon a solid brick wall, and the duration of vibration from a number of trials was eighty-eight seconds. Against a wall of lath and plaster the sound was louder, and continued only eighteen seconds.

From these experiments we may infer that, if a room were lined with wainscot of thin boards, and a space left between the wall and the wood, the loudness of the echo of a single noise would be increased, while the duration of the resonance would be diminished. If, however, the thin board were glued or cemented in solid connexion to the wall, or imbedded in the mortar, then the effect would be a feeble echo, and a long continued resonance, similar to that from the slab of marble. This was proved by first determining the length of continuance of the vibrations of a tuning-fork on a thin board, which was afterwards cemented to a flat piece of marble.

A series of experiments were next commenced with reference to the actual reflection of sound. For this purpose a parabolic mirror was employed, and the sound from a watch received on the mouth of a hearing trumpet, furnished with a tube for each ear. The focus was near the apex of the parabola, and when the watch was suspended at this point it was six inches within the plane of the outer circle of the mirror. In this case the sound was confined at its origin, and prevented from expanding. No conjugate focus was produced, but, on the contrary, the rays of light, when a candle was introduced, constantly diverged. The ticking of the watch could not be heard at all when the ear was applied to the outside of the mirror, while directly in front it was distinctly heard at the distance of thirty feet, and with the assistance of the ear trumpet at more than double that distance. When the watch was removed from the focus, the sound ceased to be audible. This method of experimenting admits of considerable precision, and enables us directly to verify, by means of sound transmitted through air, the results anticipated in the previous experiments. A piece of tissue-paper placed within the mirror, and surrounding the watch without touching it, slightly diminished the reflection. A single curtain of flannel produced a somewhat greater effect, though the reflecting power of the metallic parabola was not entirely masked by three thicknesses of flannel; and, I presume, very little change would have been perceived, had the reflector been lined with flannel glued to the surface of the metal. The sound was also audible at the distance of ten feet, when a large felt hat, without stiffening, was interposed between the watch and the mirror. Care was taken in these experiments so to surround the watch that no ray of sound could pass directly from it to the reflecting surface.

With a cylindrical mirror, having a parabolic base, very little increased reflection was perceived. The converging beams in this case were merely in a single plane, perpendicular to the mirror, and passing through the ear, while to the focal point of the spherical mirror a solid cone of rays was sent.

The reflection from the cylindrical mirror forms what is called a *caustic* in optics, while that from a spherical mirror gives a true focus, or, in other words, collects the sounds from all parts of the surface, and conveys them to one point of space. These facts furnish a ready explanation of the confusion experienced in the Hall of Representatives, which is surmounted by a dome, the under surface of which acts as an immense concave mirror, reflecting to a focus every sound which

ascends to it, leaving other points of space deficient in sonorous impulses

Water, and all liquids which offer great resistance to compression, are good reflectors of sound. This may be shown by the following experiment. When water is gradually poured into an upright cylindrical vessel, over the mouth of which a tuning-fork is vibrated, until it comes within a certain distance of the mouth, it will reflect an echo in unison with the vibrations of the fork, and produce a loud resonance. This result explains the fact, which had been observed with some surprise, that the duration of the resonance of a newly plastered room was not perceptibly less than that of one which had been thoroughly dried.

There is another principle of acoustics which has a bearing on this subject. I allude to the refraction of sound. It is well known that, when a ray of sound passes from one medium to another, a change in velocity takes place, and consequently a change in the direction or a refraction must be produced. The amount of this can readily be calculated where the relative velocities are known. In rooms heated by furnaces, and in which streams of heated air pass up between the audience and speaker, a confusion has been supposed to be produced, and distinct hearing interfered with, by this cause. Since the velocity of sound in air at 32° of Fahrenheit has been found to be 1,090 feet in a second, and since the velocity increases 1.14 feet for every degree of Fahrenheit's scale, if we know the temperature of the room, and that of the heated current, the amount of angular refraction can be ascertained. But since the ear does not readily judge of the difference of direction of two sounds emanating from the same source, and since two rays do not confuse the impression which they produce upon the ear, though they arrive by very different routes, provided they are within the limit of perceptibility, we may therefore conclude that the indistinctness produced by refraction is comparatively little. Professor Bache and myself could perceive no difference in distinctness in hearing from rays of sound passing over a chandelier of the largest size, in which a large number of gas jets were in full combustion. The fact of disturbance from this cause, however, if any exist, may best be determined by the experiment with a parabolic mirror and the hearing trumpet before described.

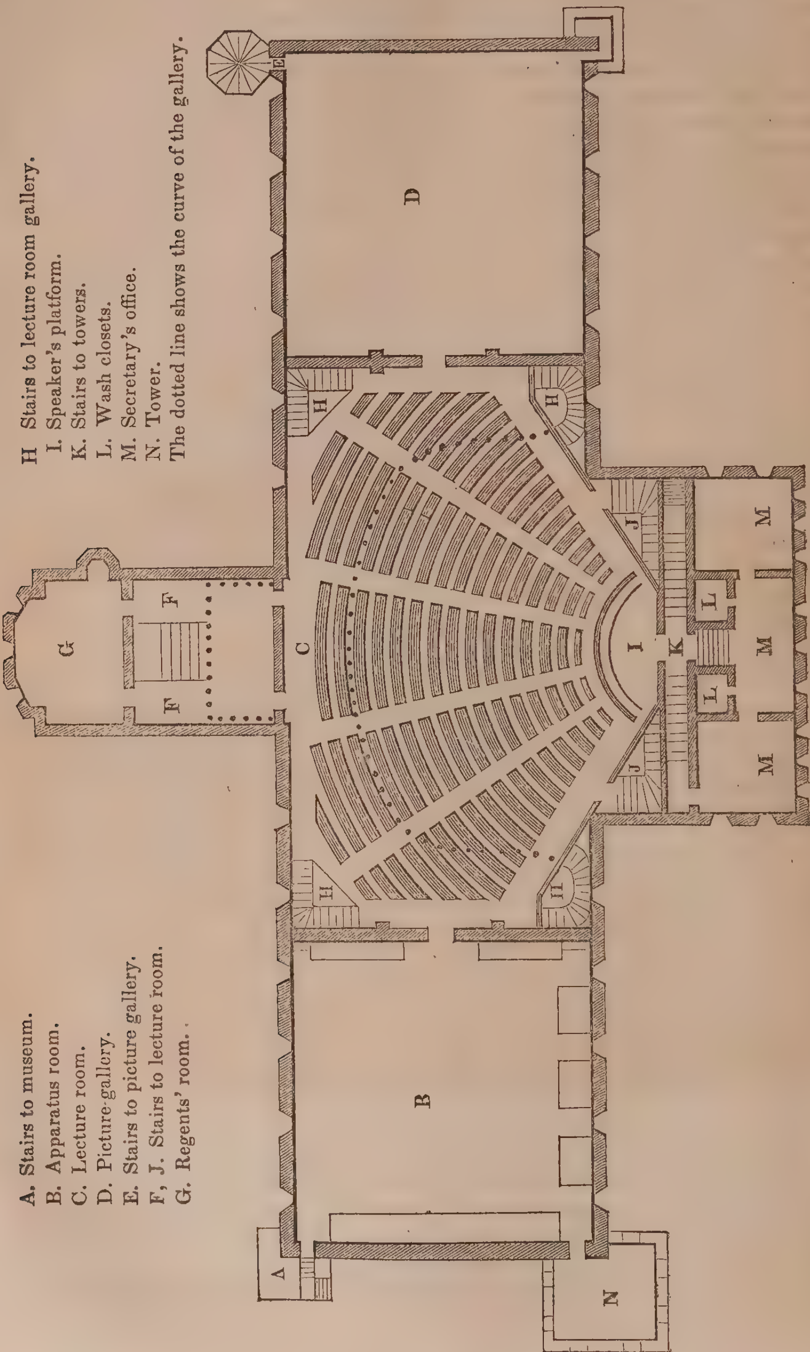
These researches may be much extended; they open a field of investigation equally interesting to the lover of abstract science and to the practical builder; and I hope, in behalf of the committee, to give some further facts with regard to this subject at another meeting.

I shall now briefly describe the lecture room, which has been constructed in accordance with the facts and principles previously stated, so far at least as they could be applied.

There was another object kept in view in the construction of this room besides the accurate hearing, namely, the distinct seeing. It was desirable that every person should have an opportunity of seeing the experiments which might be performed, as well as of hearing distinctly the explanation of them.

By a fortunate coincidence of principle, it happens that the arange-

ments for insuring unobstructed sight do not interfere with those necessary for distinct hearing.

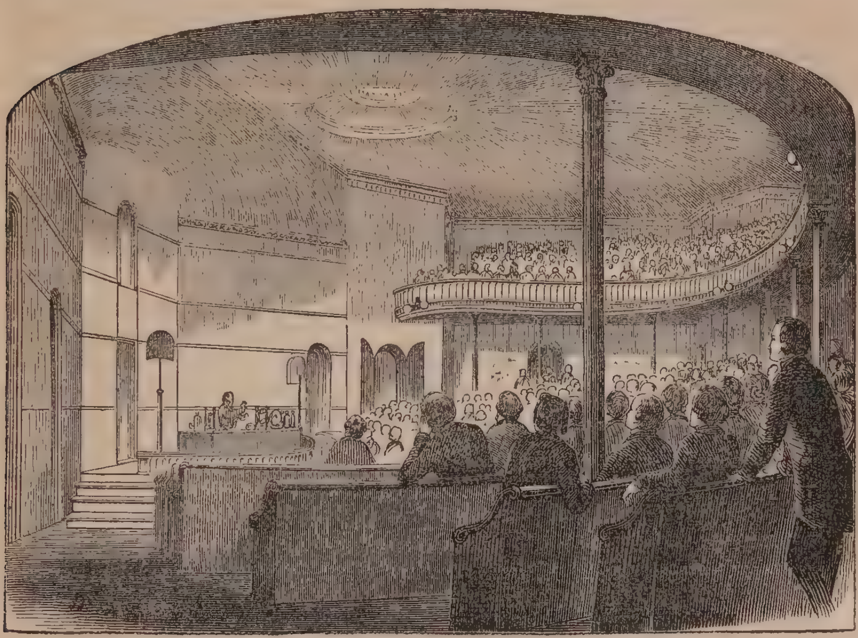


A. Stairs to museum.
B. Apparatus room.
C. Lecture room.
D. Picture-gallery.
E. Stairs to picture gallery.
F, J. Stairs to lecture room.
G. Regents' room.

H. Stairs to lecture room gallery.
I. Speaker's platform.
K. Stairs to towers.
L. Wash closets.
M. Secretary's office.
N. Tower.
The dotted line shows the curve of the gallery.

The law of Congress authorizing the establishment of the Smithsonian Institution directed that a lecture-room should be provided; and accordingly in the first plan one-half of the first story of the main building was devoted to this purpose. It was found, however, impossible to construct a room on acoustic principles in this part of the building, which was necessarily occupied by two rows of columns. The only suitable place which could be found was, therefore, on the second floor. The main building is two hundred feet long and fifty feet wide; but by placing the lecture-room in the middle of the story a greater width was obtained by means of the projecting towers.

The general form and arrangement of the room will be understood from the accompanying drawing, which exhibits a general plan of the second story of the main building. In this, G, F, F, represent the rear, and M, M, M, the front towers. The lecture-room is 100 feet in its greater dimension, and 64 feet from I to C, and 88 feet to the extremity of the upper gallery F, F. The curved dotted line represents the front of the gallery, which is in the form of a horse shoe. The dotted line in the rear tower represents the extension of the gallery into this space.



The above illustration exhibits a perspective view of the lecture-room from the west side under the gallery.

The speaker's platform is placed between two oblique walls. The corners of the room which are cut off by these walls afford recesses for the stairs into the galleries. The opposite corners are also partitioned off, so as to afford recesses for the same purpose. The ceiling is twenty-five feet high, and, therefore, within the limit of perceptibility. It is perfectly smooth and unbroken, with the exception of an oval opening nearly over the speaker's platform, through which light is admitted. The seats are arranged in curves, and were intended to rise in accordance with the *panoptic curve*, originally proposed by Professor Bache, which enables each individual to see over the head of the person immediately in front of him. The original form of the room, however, did not allow of this intention being fully realized, and therefore the rise is a little less than the curve would indicate.

The walls behind the speaker are composed of lath and plaster, and therefore have a tendency to give a more intense, though less prolonged sound than if of solid masonry. They are also arranged for exhibiting drawings to the best advantage.

The general appearance of the room is somewhat fan-shaped, and the speaker is placed as it were in the mouth of an immense trumpet. The sound directly from his voice, and that from reflection immediately behind him, is thrown forward upon the audience; and as the difference of distance travelled by the two rays is much within the limit of perceptibility, no confusion is produced by direct and reflected sound.

Again, on account of the oblique walls behind the speaker, and the multitude of surfaces, including the gallery, pillars, stair-screens, &c., as well as the audience, directly in front, all reverberation is stopped.

No echo is given off from the ceiling, for this is also within the limit of perceptibility, while it assists the hearing in the gallery by the reflection to that place of the oblique rays.

The architecture of this room is due to Captain Alexander, of the corps of topographical engineers. He fully appreciated all the principles of sound which I have given, and varied his plans until all the required conditions, as far as possible, were fulfilled.

DIRECTIONS FOR COLLECTING, PRESERVING, AND TRANSPORTING SPECIMENS OF NATURAL HISTORY.

PREPARED FOR THE USE OF THE SMITHSONIAN INSTITUTION.

By Professor S. F. BAIRD.

INTRODUCTION.

The present brief directions for collecting and preserving objects of natural history have been drawn up for the use of travellers and others who may desire elementary instruction on this subject. The general principles involved are so simple as to enable any one, with but little practice, to preserve specimens sufficiently well for the ordinary purposes of science.

In transmitting specimens to the Smithsonian Institution, recourse may be had, when practicable, to the facilities kindly authorized by the War, Navy, and Treasury Departments, in the annexed letters. Parcels collected in the vicinity of military posts in the interior may usually be sent down to the coast or the frontier in returning trains of the quartermaster's department. From the Atlantic, Pacific, or Mexican gulf coasts, they may be shipped on board storeships, revenue cutters, or other government vessels, to some convenient Atlantic seaport. While waiting for opportunities of shipment, packages can generally be deposited in custom-houses or public stores.

Where it is not convenient or practicable to make use of government facilities, the ordinary lines of transportation may be employed. When there is time enough to communicate with the Institution, instructions will be supplied as to the most eligible route; if not, then the cheapest but most reliable line should be selected. In every case the parcels should be addressed to the Smithsonian Institution, Washington, with the name of sender and locality marked on the outside. Full directions for packing specimens will be found in the pamphlet.

Collections in natural history, as complete as possible, including the commonest species, are requested from any part of the country; as also lists and descriptions of species, notes of habits, &c.

For all assistance which may be rendered, either in gathering specimens or in aiding in their transportation, full credit will be given by the Institution in the annual reports to Congress, catalogues and labels of collections, and in other ways.

§ I. GENERAL REMARKS.*

The general principle to be observed in making collections of natural history, especially in a country but little explored, is, to gather all the

* This chapter is intended especially for the guidance of travelling parties by land, and embraces many points referred to subsequently at greater length.

species which may present themselves, subject to the convenience or practicability of transportation. The number of specimens to be secured will, of course, depend upon their size, and the variety of form or condition, caused by the different features of age, sex, or season.

As the object of the Institution in making collections is not merely to obtain the different species, but also to determine their geographical distribution, it becomes important to have as full series as practicable from each locality. And in commencing such collections, the most common and abundant species should be secured first, as being most characteristic. It is a fact well known in the history of collections, that the species which, from their abundance, would be first expected, are the last to make their appearance. Thus, while the rarer mammals of the plains are tolerably well represented, the antelope, prairie dog, the various species of wolves, the black-tail deer, and others, so numerous in perfectly accessible localities, have scarcely ever been seen in a preserved state.

The first specimen procured, however imperfect, should be preserved, at least until a better can be obtained.

Where a small part only of the specimens collected can be transported, such species should be selected as are least likely to be procured in other localities or on other occasions. Among these may be mentioned reptiles, fishes, soft insects, &c.; in short, all such as require alcohol for their preservation. Dried objects, as skins, can be procured with less difficulty, and are frequently collected by persons not specially interested in scientific pursuits.

In gathering specimens of any kind, it is important to fix, with the utmost precision, the localities where they are found. This is especially desirable in reference to fishes and other aquatic animals, since they occupy a very intimate relation to the waters in which they live.

The smaller quadrupeds, of the size of a mouse, may be preserved entire in alcohol. Larger kinds should be skinned, and the skins put into alcohol, or coated on the inside with arsenic, and then dried.

The skulls of the smaller kinds may be left in the skins; those of the larger should be removed, taking care to attach some common mark by which they may be again brought together. Large animals, of or above the size of the wolf, may, for greater convenience, be skinned after the method pursued by butchers, by drawing the skin of the legs down to the toes, and there severing the joint. The skins need not be sewed up, as is directed for the smaller kinds, but rolled up into bales, after applying an abundance of arsenic and drying them. In the absence of arsenic, salt applied to the skin will answer as a preservative. Immersion in a strong brine of alum and salt will be found very efficacious. Powdered green or blue vitriol, sprinkled on the hair, will serve a good purpose in keeping off insects.

It is very important to procure the skeletons, and at all events the skulls, of all the species of mammals, in sufficient number to include all the variations of age and sex. These may be roughly prepared by cutting off the flesh, extracting the brain, and drying in the sun.

In passing through the breeding ground of species of birds whose nidification and eggs are not known, attention should be paid to secu-

ring abundant specimens of nests and eggs. When possible, the skin of the bird to which each set of eggs may belong should be secured, as well as the skins of birds generally.

A great obstacle in the way of making alcoholic collections while on a march, has been found in the escape of the spirits and the friction of the specimens, as well as in the mixing up of those from different localities. All these difficulties have been successfully obviated by means of the following arrangement: instead of using glass jars, so liable to break, or even wooden kegs, so difficult of stowage, a square copper can should be procured, having a large mouth with a cap fitting tightly over it, either by a screw, or otherwise. The can should be enclosed in a wooden box, or may be made to fit to a division of a pannier, to be slung across the back of a mule. Several small cans, in capacity of from a half to one-third of a cubic foot, or even less, will be better than one large one. Small bags of mosquito netting, lino, crinoline, or other porous material, should be provided, made in shape like a pillow-case, and open at one end; these may be from six to fifteen inches long. When small fishes, reptiles, or other specimens are procured in any locality, they may be placed indiscriminately in one or more of these bags (the mouths of which are to be tied up like a sack,) and then thrown into the alcohol. Previously, however, a label of parchment, leather, or stout paper should be placed inside the bag, containing the name of the locality or other mark, and written in ordinary ink. The label, if dry before being placed in the bag, will retain its writing unchanged for a long time. The locality, or its number, should also be coarsely marked with a red pencil on the outside of the bag. In this way, the specimens, besides being readily identified, are preserved from rubbing against each other, and consequent injury. Still further to facilitate this object, an India rubber gas-bag may be employed to great advantage, by introducing it into the vessel, and inflating until all vacant space is filled up by the bag, and the consequent displacement of the spirit. When additional specimens are to be added, a portion of the air may be let out, and the bag afterwards again inflated. Should this arrangement be found impracticable, a quantity of tow, cotton, or rags, kept over the specimens, will be found useful in preventing their friction against each other, or the sides of the vessel.

The larger snakes should be skinned, as indicated hereafter, and the skins thrown into alcohol. Much space will in this way be saved. Smaller specimens may be preserved entire, together with lizards, salamanders, and small frogs. All of these that can be caught should be secured and preserved. The head, the legs with the feet, the tail, in fact the entire skin of turtles, may be preserved in alcohol; the soft parts then extracted from the shell, which is to be washed and dried.

Every stream, and indeed, when possible, many localities in each stream, should be explored for fishes, which are to be preserved as directed. For these, as well as the other alcoholic collections, the lino bags are very useful.

Great attention should be paid to procuring many specimens of the different kinds of small fishes, usually known as minnows, shiners,

chubs, &c. Among these will always be found the greatest variety of species, some never exceeding an inch in length. These fish are generally neglected under the idea that they are merely the young of larger kinds; even if they should prove to be such, however, they will be none the less interesting. Different forms will be found in different localities. Thus the *Etheostoma*, or Darters, and the *Cottus*, live under stones, or among gravel, in shallow clear streams, lying flat on the ground. Others will be dislodged by stirring under roots or shelving banks along the water's edge. The *Melanura*, or mud fish (a few inches in length,) exist *in* the mud of ditches, and are secured by stirring up this mud into a thin paste with the feet, and then drawing a net through. The sticklebacks and cyprinodonts live along the edges of fresh and salt water. The *Zygonectes* swim in pairs slowly along the surface of the water, the tip of the nose generally exposed. They generally have a broad black stripe on the side. By a careful attention to these hints, many localities supposed to be deficient in species of fishes, will be found to yield a large number.

The alcohol used on a march may be supplied with tartar emetic. This, besides adding to its preservative power, will remove any temptation to drink it, on the part of unscrupulous persons.

Nearly all insects, scarcely excepting the *Lepidoptera*, can be readily preserved in alcohol. Crabs and small shells may likewise be treated in the same manner.

It is not usually possible to collect minerals, fossils, and geological specimens in very great mass while travelling. The fossils selected should be as perfect as possible; and especial care should be paid to procuring the bones and teeth of vertebrate animals. Of minerals and rocks, specimens as large as a hickory-nut will, in many cases, be sufficient for identification.

Where collections cannot be made in any region, it will be very desirable to procure lists of all the known species, giving the names by which they are generally recognized, as well as the scientific name, when this is practicable. The common names of specimens procured should also be carefully recorded.

All facts relating to the habits and peculiarities of the various species of animals should be carefully recorded in the note book, especially those having relation to the peculiarities of the season of reproduction, &c. The accounts of hunters and others should also be collected, as much valuable information may thus be secured. The colors of the reptiles and fishes when alive should always be given, when practicable, or, still better, painted on a rough sketch of the object.

LIST OF APPARATUS USEFUL FOR TRAVELLING PARTIES.

1. Two leather panniers, supplied with back strap for throwing across a mule. One of these is intended to contain the copper kettles, and their included alcohol, together with the nets and other apparatus; the other to hold the botanical apparatus, skins of animals, minerals, &c. These, when full, should not weigh more than one hundred and fifty pounds the pair.

2. Two copper kettles in one of the panniers, to contain the alcohol for such specimens as require this mode of preservation, viz: reptiles, fishes, small quadrupeds, most insects, and all soft invertebrates. The alcohol, if over 80 per cent., should have one-fourth of water added.

3. An iron wrench to loosen the screw-caps of the copper kettles, when too tight to be managed by hand.

4. Two India rubber bags, one for each kettle. These are intended to be inflated inside of the kettles, and by displacing the alcohol cause it to rise to the edge of the brass cap, and thus fill the kettle. Unless this is done, and any unoccupied space thus filled up, the specimens will be washed against the sides of the vessel, and much injured.

5. Small bags made of lino, mosquito netting or cotton, of different sizes, and open at one end. These are intended, in the first place, to separate the specimens of different localities from each other; and, in the second place, to secure them from mutual friction or other injury. The number or name corresponding to the locality is to be marked on the outside with red chalk, or written with ink on a slip of parchment, and dropped inside. The specimens are then to be placed in the bag, a string tied round the open end, and the bag thrown into alcohol. The ink of the parchment must be dry before the slip is moistened in any way.

N. B. Fishes and reptiles over five or six inches in length should have a small incision made in the abdomen, to facilitate the introduction of the alcohol. Larger snakes and small quadrupeds may be skinned, and the skins placed in alcohol.

6. Red chalk pencils for marking the bags.

7. Parchment to serve as labels for the bags. This may also be cut up into labels, and fastened by strings to such specimens as are not suited for the bags. Leather, kid, buckskin, &c., will also answer this purpose.

8. Fishing-line and hooks.

9. Small seines for catching fishes in small streams. The two ends should be fastened to brails or sticks (hoe-handles answer well), which are taken in the hands of two persons, and the net drawn both up and down stream. Fishes may often be caught by stirring up the gravel or small stones in a stream, and drawing the net rapidly down the current. Bushes or holes along the banks may be inclosed by the nets, and stirred so as to drive out the fishes, which usually lurk in such localities. These nets may be six or eight feet long.

10. Casting-net.

11. Alcohol. About five gallons to each travelling party. This should be about 80 per cent. in strength, and medicated by the addition of one ounce of tartar emetic to one gallon of alcohol, to prevent persons from drinking it.

12. Arsenic in two-pound tin canisters. This may be applied to the moist skins of birds and quadrupeds, either dry or mixed with alcohol.

13. Tartar emetic for medicating the alcohol, as above.

14. Cotton or tow for stuffing out the heads of birds and mammals. To economize space, but little should be put into the bodies of the animals. The skulls of the quadrupeds had better be removed from the skins, but carefully preserved with a common mark.

15. Paper for wrapping up the skins of birds and small quadrupeds, each separately. The paper supplied for botanical purposes will answer for this.

16. Butcher-knife, scissors, needles, and thread, for skinning and sewing up animals.

17. Blank labels of paper with strings attached for marking localities, sex, &c., and tying to the legs of the dried skins, or to the stems of plants.

18. Portfolio for collecting plants.

19. Press for drying plants between the blotting paper. Pressure is applied by straps.

20. Very absorbent paper for drying plants.

21. Stiffer paper for collecting plants in the field. The same paper may be used for wrapping skins of birds and quadrupeds, as well as minerals and fossils.

22. Small bottles for collecting and preserving insects.

23. Geological hammer.

24. Double-barrelled gun and rifle.

25. Fine shot for small birds and mammals. Numbers 3, 6, and 9, are proper sizes: the latter should always be taken.

26. A pocket case of dissecting instruments will be very convenient.

27. Blowpipe apparatus for mineralogical examinations.

28. Pocket vial for insects.

29. Bottle of ether for killing insects.

30. Insect pins.

31. Cork-lined boxes.

§ II. INSTRUMENTS, PRESERVATIVE MATERIALS, &c.

1. IMPLEMENTS FOR SKINNING.

The implements generally required in skinning vertebrated animals are: A sharp knife or a scalpel. 2. A pair of sharp-pointed scissors, and one with strong short blades. 3. Needles and thread for sewing up the incisions in the skin. 4. A hook by which to suspend the carcass of the animal during the operation of skinning. To prepare the hook, take a string, of from one to three feet in length, and fasten one end of it to a stout fish-hook which has had the barb broken off. By means of a loop at the other end, the string may be suspended to a nail or awl, which, when the hook is inserted into the body of an animal, will give free use of both hands in the operation of skinning.

2. PRESERVATIVES.

The best material for the preservation of skins of animals consists of powdered arsenious acid, or the common arsenic of the shops. This may be used in two ways, either applied in dry powder to the moist skin, or else mixed with alcohol or water to the consistency of molasses, and put on with a brush. A little camphor may be added to the alcoholic solution. There are no satisfactory substitutes for arsenic

but, in its entire absence, corrosive sublimate, arsenical soap, camphor, alum, &c., may be employed.

The proper materials for stuffing out skins will depend much upon the size of the animal. For small birds and quadrupeds, cotton will be found most convenient; for the larger, tow. For those still larger, dry grass, straw, sawdust, bran, or other vegetable substances, may be used. Whatever substance be used care must be taken to have it perfectly dry. Under no circumstances should animal matter, as hair, wool, or feathers, be employed.

§ III. SKINNING AND STUFFING.

1. BIRDS.

Whenever convenient the following notes should be made previous to commencing the operation of skinning, as they will add much to the value of the specimens:

1. The length, in inches, from tip of bill to the end of the tail; the distance between the two extremities of the outstretched wings; and the length of the wing from the carpal or wrist-joint. The numbers may be recorded as follows: 44, 66, 12, (as for a swan,) without any explanation; it being well understood that the above measurements follow each other in a fixed succession. These numbers may be written on the back of the label attached to each specimen.

2. The color of the eyes, that of the feet, bill, gums, membranes, caruncles, &c.

3. The date, the locality, and the name of the collector.

4. The sex. All these points should be recorded on the label.

Immediately after a bird is killed, the holes made by the shot, together with the mouth and internal or posterior nostrils, should be plugged up with cotton, to prevent the escape of blood and the juices of the stomach. A long narrow paper cone should be made; the bird, if small enough, thrust in, head foremost, and the open end folded down, taking care not to break or bend the tail feathers in the operation.*

When ready to proceed to skinning, remove the old cotton from the throat, mouth, and nostrils, and replace it by fresh. Then take the dimensions from the point of the bill to the end of the tail, from the tip of one wing to that of the other, when both are extended, and from the tip of the wing to the first or carpal joint, as already indicated.

This being done, make an incision through the skin only, from the lower end of the breast bone to the anus. Should the intestines protrude in small specimens, they had better be extracted, great care being taken not to soil the feathers. Now proceed carefully to separate the skin on each side from the subjacent parts, until you reach the knee and expose the thigh; when, taking the leg in one hand, push or thrust the knee up on the abdomen, and loosen the skin around

* Crumpled or bent feathers may have much of their elasticity and original shape restored by dipping in hot water.

it until you can place the scissors or knife underneath, and separate the joint with the accompanying muscles. Place a little cotton between the skin and the body to prevent adhesion. Loosen the skin about the base of the tail, and cut through the vertebræ at the last joint, taking care not to sever the bases of the quills. Suspend the body by inserting the hook into the lower part of the back or rump, and invert the skin, loosening it carefully from the body. On reaching the wings, which had better be relaxed previously by stretching and pulling, loosen the skin from around the first bone, and cut through the middle of it, or, if the bird be small enough, separate it from the next at the elbow. Continue the inversion of the skin by drawing it over the neck, until the skull is exposed. Arrived at this point, detach the delicate membrane of the ear from its cavity in the skull, if possible, without cutting or tearing it; then, by means of the thumb-nails, loosen the adhesion of the skin to the other parts of the head, until you come to the very base of the mandibles, taking care to cut through the white nictitating membrane of the eye, when exposed, without lacerating the ball. Scoop out the eyes, and by making one cut on each side of the head, through the small bone connecting the base of the lower jaw with the skull, another through the roof of the mouth at the base of the upper mandible, and between the jaws of the lower, and a fourth through the skull behind the orbits, and parallel to the roof of the mouth, you will have freed the skull from all the accompanying brain and muscle. Should anything still adhere, it may be removed separately. In making the first two cuts care must be taken not to injure or sever the zygoma, a small bone extending from the base of the upper mandible to the base of the lower jaw-bone. Clean off every particle of muscle and fat from the head and neck, and, applying the preservative abundantly to the skull, inside and out, as well as to the skin, restore these parts to their natural position. In all the preceding operations the skin should be handled as near the point of adhesion as possible, especial care being taken not to stretch it.

Finely powdered plaster of Paris, chalk, or whiting, may be used to great advantage by sprinkling on the exposed surface of the carcass and inside of skin to absorb the grease and blood.

The next operation is to connect the two wings inside of the skin by means of a string, which should be passed between the lower ends of the two bones forming the forearm, previously, however, cutting off the stump of the arm, if still adhering at the elbow. Tie the two ends of the strings so that the wings shall be kept at the same distance apart as when attached to the body. Skin the leg down to the scaly part, or tarsus, and remove all the muscle. Apply the arsenic to the bone and skin, and, wrapping cotton round the bone, pull it back to its place. Remove all the muscle and fat which may adhere to the base of the tail or the skin, and put on plenty of the preservative wherever this can be done. Lift up the wing, and remove the muscle from the forearm by making an incision along it, or in many cases the two joints may be exposed by carefully slipping down the skin towards the wrist-joint, the adhesion of the quills to the bone being loosened.

The bird is now to be restored to something like its natural shape by means of a filling of cotton or tow. Begin by opening the mouth and putting cotton into the orbits and upper part of the throat, until these parts have their natural shape. Next take tow or cotton, and, after making a roll rather less in thickness than the original neck, put it into the skin, and push firmly into the base of the skull. By means of this you can reduce or contract the neck if too much stretched. Fill the body with cotton, not quite to its original dimensions, and sew up the incision in the skin, commencing at the upper end, and passing the needle from the inside outwards; tie the legs and mandibles together, adjust the feathers, and, after preparing a cylinder of paper the size of the bird, push the skin into it so as to bind the wings closely to the sides. The cotton may be put in loosely, or a body the size of the original made by wrapping with threads. If the bird have long legs and neck, these had better be folded down over the body, and allowed to dry in that position. Economy of space is a great object in keeping skins, and such birds as herons, geese, swans, &c., occupy too much room when outstretched.

In some instances, as among ducks, woodpeckers, &c., the head is so large that the skin of the neck cannot be drawn over it. In such cases, skin the neck down to the base of the skull, and cut it off there. Then draw the head out again, and, making an incision on the outside, down the back of the skull, skin the head. Be careful not to make too long a cut, and to sew up the incision again.

The sex of the specimen may be ascertained after skinning, by making an incision in the side near the vertebræ, and exposing the inside surface of the "small of the back." The generative organs will be found tightly bound to this region, (nearly opposite to the last ribs,) and separating it from the intestines. The testicles of the male will be observed as two spheroidal or ellipsoidal whitish bodies, varying with the season and species, from the size of a pin's head to that of a hazel-nut. The ovaries of the female, consisting of a flattened mass of spheres, variable in size with the season, will be found in the same region.

For transportation, each skin of mammals, as well as of birds, should, when possible, be wrapped in paper.

2. MAMMALS.

The mode of preparing mammals is precisely the same as for birds, in all its general features. Care should be taken not to make too large an incision along the abdomen. The principal difficulty will be experienced in skinning the tail. To effect this, pass the slipknot of a piece of strong twine over the severed end of the tail, and, fastening the vertebræ firmly to some support, pull the twine towards the tip until the skin is forced off. Should the animal be large, and an abundance of preservative not at hand, the skin had better remain inverted. In all cases it should be thoroughly and rapidly dried.

The tails of some mammalia cannot be skinned as directed above. This is particularly the case with beavers, opossums, and those species which use their tail for prehension or locomotion. Here the tail is

usually supplied with numerous tendinous muscles, which require it to be skinned by making a cut along the lower surface or right side, nearly from one end to the other, and removing the bone and flesh. It should then be sewed up again, after previous stuffing.

For the continued preservation of hair or fur of animals against the attacks of moths and other destructive insects, it will be necessary to soak the skins in a solution of corrosive sublimate in alcohol or whiskey, allowing them to remain from one day to several weeks, according to the size. After removal, the hair must be thoroughly washed or rinsed in clean water, to remove as much as possible of the sublimate; otherwise, exposure to light will bleach all the colors.

Finely powdered green vitriol, or copperas, sprinkled on either hair or feathers will have an excellent effect in keeping out moths. Covering with tobacco leaves will also answer the same end.

In some instances, large skins may be preserved by being salted down in casks.

3. REPTILES.

The larger *lizards*, such as those exceeding twelve or eighteen inches in length, may be skinned according to the principles above mentioned, although preservation in spirit, when possible, is preferable for all reptiles.

Large *frogs* and *salamanders* may likewise be skinned, although cases where this will be advisable are very rare.

Turtles and *large snakes* will require this operation.

To one accustomed to the skinning of birds, the skinning of frogs or other reptiles will present no difficulties.

The skinning of a snake is still easier. Open the mouth and separate the skull from the vertebral column, detaching all surrounding muscles adherent to the skin. Next, tie a string round the stump of the neck thus exposed, and, holding on by this, strip the skin down to the extremity of the tail. The skin thus inverted should be restored to its proper state, and then put in spirit or stuffed, as convenient. Skins of reptiles may be stuffed with either sand or sawdust, by the use of which their shape is more easily restored.

Turtles and tortoise are more difficult to prepare in this way, although their skinning can be done quite rapidly. "The breastplate must be separated by a knife or saw from the back, and, when the viscera and fleshy parts have been removed, restored to its position. The skin of the head and neck must be turned inside out, as far as the head, and the vertebræ and flesh of the neck should be detached from the head, which, after being freed from the flesh, the brain, and the tongue, may be preserved with the skin of the neck. In skinning the legs and the tail, the skin must be turned inside out, and, the flesh having been removed from the bones, they are to be returned to their places by redrawing the skin over them, first winding a little cotton or tow around the bones to prevent the skin adhering to them when it dries."—RICHARD OWEN.

Another way of preparing these reptiles is as follows: Make two incisions, one from the anterior end of the breastplate to the sym-

physis of the lower jaw, and another from the posterior end of the breastplate to the vent or tip of the tail; skin off these regions and remove all fleshy parts and viscera without touching the breatplate itself. Apply preservative, stuff, and sew up again both incisions.

"When turtles, tortoises, crocodiles, or alligators, are too large to be preserved whole in liquor, some parts, as the head, the whole viscera stripped down from the neck to the vent, and the cloaca, should be put into spirits or solution."—R. OWEN.

4. FISHES.

As a general rule, fishes, when not too large, are best preserved entire in spirits.

Nevertheless, they may be usefully skinned and form collections, the value of which is not generally appreciated. In many cases, too, when spirits or solutions cannot be procured, a fish may be preserved which would otherwise be lost.

There are two modes of taking the skin of a fish: 1. The whole animal can be skinned and stuffed like a bird, mammal, or reptile. 2. One-half of the fish can be skinned, and nevertheless its natural form preserved.

Sharks, *skates*, *sturgeons*, *garpikes* or *garfishes*, *mudfishes* and all those belonging to the natural orders of *Placoids* and *Ganoids*, should undergo the same process as given above for birds, mammals, and reptiles. An incision should be made along the right side, the left always remaining intact, or along the belly. The skin is next removed from the flesh, the fins cut at their bases under the skin, and the latter inverted until the base of the skull is exposed. The inner cavity of the head should be cleaned, an application of preservative made, and the whole, after being stuffed in the ordinary way, sewed up again. Fins may be expanded when wet, on a piece of stiff paper, which will keep them sufficiently stretched for the purpose. A varnish may be passed over the whole body and fins, to preserve somewhat the color.

In the case of *Ctenoids*, perches, and allied genera, and *Cycloids*, trouts, suckers, and allied genera, one half of the fish may be skinned and preserved. To effect this, lay the fish on a table with the left side up; the one it is intended to preserve. Spread out the fins by putting underneath each a piece of paper, to which it will adhere on drying. When the fins are dried, turn the fish over, cut with scissors or a knife all around the body, a little within the dorsal and ventral lines, from the upper and posterior part of the head, along the back to the tail, across the base of the caudal fin down, and thence along the belly to the lower part of the head again. The dorsal, caudal, and anal fins, cut below their articulations. This done, separate the whole of the body from the left side of the skin, commencing at the tail. When near the head, cut off the body with the right ventral and pectoral fins, and proceed by making a section of the head and removing nearly the half of it. Clean the inside, and pull out the left eye, leaving only the cornea and pupil. Cut a circular piece of black paper of the size of the orbit and place it close to the pupil.

Apply the preservative; fill the head with cotton as well as the body. Turn over the skin and fix it on a board prepared for that purpose. Pin or tack it down at the base of the fins. Have several narrow bands of paper to place across the body in order to give it a natural form, and let it dry. The skins may be taken off the board or remain fixed to it, when sent to their destination, where they should be placed on suitable boards of proper size, for permanent preservation.

Such a collection of well prepared fishes will be useful to the practical naturalist, and illustrate, in a more complete matter, to the public, the diversified forms and characters of the class of fishes which specimens preserved in alcohol do not so readily show.

These skins may also be preserved in alcohol.

§ IV. PRESERVING IN LIQUIDS, AND BY OTHER MODES BESIDES SKINNING.

1. GENERAL REMARKS.

The best material for preserving animals of moderate size is alcohol. When spirits cannot be obtained, the following substitutes may be used:

I. Goadby's Solution.—A. *The aluminous fluid*, composed of rock-salt, 4 ounces; alum, 2 ounces; corrosive sublimate, 4 grains; boiling water, 2 quarts. B. *The saline solution*, composed of rock-salt, 8 ounces; corrosive sublimate, 2 grains; boiling water, 1 quart. To be well stirred, strained, and cooled.

II. A strong brine, to be used as hereafter indicated for Goadby's solution.

III. In extreme cases, dry salt may be used, and the specimens salted down like herring, &c.

The alcohol, when of the ordinary strength, may be diluted with one-fifth of water, unless it is necessary to crowd the specimens very much. The fourth proof whiskey of the distillery, or the high wines, constituting an alcohol of about 60 per cent., will be found best suited for collections made at permanent stations and for the museum. Lower proofs of rum or whiskey will also answer, but the specimen must not be crowded at all.

To use Goadby's solution, the animal should first be macerated for a few hours in fresh water, to which about half its volume of the concentrated solution may then be added. After soaking thus for some days, the specimens may be transferred to fresh concentrated solution. When the aluminous fluid is used to preserve vertebrate animals, these should not remain in it for more than a few days; after this they are to be soaked in fresh water, and transferred to the saline solution. An immersion of some weeks in the aluminous fluid will cause a destruction of the bones. Specimens must be kept submerged in these fluids. The success of the operation will depend very much upon the use of a weak solution in the first instance, and a change to the saturated fluid by one or two intermediate steps.

The collector should have a small keg, jar, tin box, or other suitable vessel, partially filled with liquor, into which specimens may be thrown

(alive if possible) as collected. The entrance of the spirit into the cavities of the body should be facilitated by opening the mouth, making a small incision in the abdomen a half or one inch long, or by injecting the liquor into the intestines through the anus, by means of a small syringe. After the animal has soaked for some weeks in this liquor, it should be transferred to fresh. Care should be taken not to crowd the specimens too much. When it is impossible to transfer specimens to fresh spirits from time to time, the strongest alcohol should be originally used.

To pack the specimens for transportation, procure a small keg, which has been properly swelled, by allowing water to stand in it for a day or two, and from this extract the head by knocking off the upper hoops. Great care must be taken to make such marks on the hoops and head, as will assist in their being replaced in precisely the same relative position to each other and the keg that they originally held. At the bottom of the keg place a layer of tow or rags, moistened in liquor, then one of specimens, then another of tow and another of specimens, and so on alternately until the keg is *entirely filled*, exclusive of the spirit. Replace the head, drive down the hoops, and fill completely with spirits by pouring through the bung-hole. Allow it to stand at least half an hour, and then supplying the deficiency of the liquor, insert the bung and fasten it securely. An oyster-can or other tin vessel may be used to great advantage, in which case the aperture should be soldered up and the vessel inclosed in a box. A glass jar or bottle may also be employed, but there is always a risk of breaking and leaking. In the absence of tow, or rags, chopped straw, fine shavings, or dry grass may be substituted.

It will conduce greatly to the perfect preservation of the specimens, during transportation, if each one is wrapped up in cotton cloth, or even paper. A number of smaller specimens may be rolled successively in the same wrapper. In this way friction, and the consequent destruction of scales, fins, &c., will be prevented almost entirely. The travelling bags, already described, will answer the same purpose.

Should the specimens to be packed vary in size, the largest should be placed at the bottom. If the disproportion be very great, the delicate objects at the top must be separated from those below, by means of some immovable partition, which, in the event of the vessel being inverted, will prevent crushing. The most imperative rule, however, in packing, is to have the vessel perfectly full, any vacancy exposing the whole to the risk of loss.

It is sometimes necessary to guard against the theft of the spirit employed, by individuals who will not be deterred from drinking it by the presence of reptiles, &c. This may be done by adding a small quantity of tartar emetic, ipecacuanha, quassia, or some other disagreeable substance. The addition of corrosive sublimate will add to the preservative power of the spirit.

2. VERTEBRATA.

Fishes under five or six inches in length need not have the abdominal incision. Specimens with the scales and fins perfect should be selected, and, if convenient, stitched, pinned, or wrapped in bits of

muslin, &c., to preserve the scales. In general, fishes under twelve or fifteen inches in length should be chosen. The skins of larger ones may be put in liquor. It is important to collect even the smallest. The same principles apply to the other vertebrata.

The smallest and most delicate specimens may be placed in bottles or vials, and packed in the larger vessels with the other specimens.

3. INVERTEBRATA.

Insects, Bugs, &c.—The harder kinds may be put in liquor, as above, but the vessel or bottle should not be very large. Butterflies, wasps, flies, &c., may be pinned in boxes, or packed in layers with soft paper or cotton. Minute species should be carefully sought under stones, bark, dung, or flowers, or swept with a small net from grass or leaves. They may be put in quills, small cones of paper, or in glass vials. They can be readily killed by immersing the bottles, &c., in which they are collected, in hot water, or exposing them to the vapor of ether.

When possible, a number of oz. or 2 oz. vials, with very wide mouths, well stopped by corks, should be procured, in which to place the more delicate invertebrata, as small crustacea, worms, mollusca, &c.

It will frequently be found convenient to preserve or transport insects pinned down in boxes. The bottoms of these are best lined with cork or soft wood. The accompanying figures will explain, better than any description, the particular part of different kinds of insects through which the pin is to be thrust: beetles being pinned through the right wing-cover or elytra; all others through the middle of the thorax.

The traveller will find it very convenient to carry about him a vial having a broad mouth, closed by a tight cork. In this should be contained a piece of camphor, or, still better, a sponge soaked in ether, to kill the insects collected. From this the specimens should be transferred to other bottles. They may, if not hairy, be killed by immersing directly in alcohol.

The camphor should always be fixed in the box containing insects, as it would break the feet and antennæ of the latter if in a loose and crystalline state. It may be kept in a piece of muslin or canvass, and then pinned at the bottom of the box.

Sea-urchins and starfishes may also be dried, after having been previously immersed for a minute or two in boiling water, and packed up in cotton, or any soft material which may be at hand.

The hard parts of coral and shells of mollusca may also be preserved in a dried state. The soft parts are removed by immersing the animals for a minute or two in hot water, and washing clean afterwards. The valves of bivalve shells should be brought together by a string.

Wingless insects, such as spiders, scorpions, centipedes or thousand-legs, earth-worms, hair-worms, and generally all worm-like animals found in the water, should be preserved in alcoholic liquor, and in small bottles or vials.

§ V. EMBRYOS.

Much of the future progress of zoology will depend upon the extent and variety of the collections which may be made of the embryos and fœtuses of animals. No opportunity should be omitted to procure these and preserve them in spirits. All stages of development are equally interesting, and complete series for the same species would be of the highest importance. Whenever any female mammal is killed, the uterus should be examined for embryos. When eggs of birds, reptiles, or fish are emptied of their young, these should be preserved. It will be sufficiently evident that great care is required to label the specimens, as in most cases it will be impossible to determine the species from the zoological characters.

§ VI. NESTS AND EGGS.

Nothing forms a more attractive feature in a museum, or is more acceptable to amateurs, than the nests and eggs of birds. These should be collected whenever they are met with, and in any amount procurable for each species, as they are always in demand for purposes of exchange. Hundreds of eggs of *any* species with their nests (or without, when not to be had) will be gladly received.

Nests require little preparation beyond packing so as to be secure from crumbling or injury. The eggs of each nest, when emptied, may be replaced in it and the remaining space filled with cotton.

Eggs, when fresh, and before the chick has formed, may be emptied by making a small pin-hole at each end, and blowing or sucking out the contents. Should hatching have already commenced, an aperture may be made in one side by carefully pricking with a fine needle round a small circle or ellipse, and thus cutting out a piece. The larger kinds should be well washed inside, and all allowed to dry before packing away. If the egg be too small for the name, a number should be marked with ink corresponding to a memorandum list. Little precaution is required in packing, beyond arranging in layers with cotton and having the box entirely filled.

The eggs of reptiles, provided with a calcareous shell, can be prepared in a similar way.

The eggs of fishes, salamanders, and frogs may be preserved in spirits, and kept in small vials or bottles. A label should never be omitted.

§ VII. SKELETONIZING.

Skulls of animals may be prepared by boiling in water for a few hours. A little potash or lye added will facilitate the removal of the flesh.

Skeletons may be roughly prepared by skinning the animal and removing all the viscera, together with as much of the flesh as possible. The bones should then be exposed to the sun or air until completely dried. Previously, however, the brain of large animals should be removed by separating the skull from the spine, and extracting

the contents through the large hole in the back of the head. In case it becomes necessary to disjoint a skeleton, care should be taken to attach a common mark to all the pieces, especially when more than one individual is packed in the same box.

Skulls and skeletons may frequently be picked up already cleaned by other animals or exposure to weather. By placing small animals near an ant's nest, or in water occupied by tadpoles, or small crustacea, very beautiful skeletons may often be obtained. The sea-beach sometimes affords rich treasures in the remains of porpoises, whales, large fishes, as sharks, and other aquatic species.

§ VIII. PLANTS.

The collector of plants requires but little apparatus; a few quires or reams of unsized paper, of folio size, will furnish all that will be needed. The specimens, as gathered, may be placed in a tin box, or, still better, in a portfolio of paper, until reaching home. About forty or fifty sheets of the paper should be put into the portfolio on setting out on an excursion. Put the specimens of each species in a separate sheet as fast as gathered from the plant, taking a fresh sheet for each additional species. On returning to camp place these sheets (without changing or disturbing the plants) between the absorbent drying papers in the press, and draw the straps tight enough to produce the requisite pressure. The next day the driers may be changed, and those previously used laid in the sun to dry; this to be continued until the plants are perfectly dry. If paper and opportunities of transportation be limited, several specimens from the same locality may be combined in the same sheet after they are dry.

Place in each sheet a slip of paper having a number or name of locality written on it corresponding with a list kept in a memorandum book. Record the day of the month, locality, size, and character of the plant, color of flower, fruit, &c.

If the stem is too long, double it or cut it in two lengths. Collect, if possible, half a dozen specimens of each kind. In the small specimens collect the entire plant, so as to show the root.

In many instances old newspapers will be found to answer a good purpose both in drying and in keeping plants, although the unprinted paper is best—the more porous and absorbent the better.

When not travelling pressure may be most conveniently applied to plants by placing them between two boards, with a weight of about fifty pounds laid on the top.

While on a march the following directions for collecting plants, drawn up by Major Rich, are recommended:

Have thick cartridge, or envelop paper, folded in *quarto* form, and kept close and even by binding with strong cord; newspapers will answer, but are liable to chafe and wear out; a few are very convenient to mix in with the hard paper as dryers. This herbarium may be rolled up in the blanket while travelling, and placed on a pack-animal. The specimens collected along the road may be kept in the crown of the hat when without a collecting box, and placed in paper at noon or at night. Great care should be taken to keep the papers dry and

free from mould. When there is not time at noon to dry the papers in the sun they should be dried at night by the fire, when, also, the dried specimens are placed at the bottom of the bundle, making room on top for the next day's collection. A tin collecting box is very necessary; plants may be preserved for two or three days in one if kept damp and cool. It is also convenient in collecting *land shells*, which is generally considered part of a botanist's duty. A collector should also always be provided with plenty of ready made seed papers, not only for preserving seeds, but mosses and minute plants. Many seeds and fruits cannot be put in the herbarium, particularly if of a succulent nature, causing mouldiness, and others form irregularities and inequalities in the papers, thus breaking specimens and causing small ones and seeds to drop out. Fruits of this kind should be numbered to correspond with the specimen, and kept in the saddle-bag, or some such place. It is necessary, in order to make good specimens, to avoid heavy pressure and keep the papers well dried, otherwise they get mouldy, turn black, or decay.

The seeds and fruits of plants should be procured whenever practicable, and slowly dried. These will often serve to reproduce a species, otherwise not transportable or capable of preservation.

On board ship it is all-important to keep the collections from getting wet with salt water. The papers can generally be dried at the galley. The whole herbarium should be exposed to the sun as often as possible, and frequently examined, and the mould brushed off with a feather or camel-hair pencil.

In collecting algæ, corallines, or the branched, horny, or calcareous corals, care should be taken to bring away the entire specimen with its base or root. The coarser kinds may be dried in the air, (but not exposed to too powerful a sun,) turning them from time to time. These should not be washed in fresh water, if to be sent any distance. The more delicate species should be brought home in salt water, and washed carefully in fresh, then transferred to a shallow basin of clean fresh water, and floated out. A piece of white paper of proper size is then slipped underneath, and raised gently out of the water with the specimen on its proper surface. After finally adjusting the branches with a sharp point or brush, the different sheets of specimens are to be arranged between blotters of bibulous paper and cotton cloth, and subjected to gentle pressure. These blotters must be frequently changed till the specimens are dry.

§ IX. MINERALS AND FOSSILS.

The collections in mineralogy and palæontology are, amongst all, those which are most easily made; whilst, on the other hand, their weight, especially when on a march, will prevent their being gathered on an extensive scale.

All the preparation usually needed for preserving minerals and fossils consists in wrapping the specimens separately in paper, with a label inside for the locality, and packing so as to prevent rubbing. Crumbling fossils may be soaked to advantage in a solution of glue.

Fossils of all kinds should be collected. Minerals and samples of

rocks are also desirable. The latter should be properly selected, and cut to five by three inches of surface and one to two inches thick.

The vertebrate fossils of North America are of the highest interest to naturalists. These are found in great abundance in those portions known as "Mauvaises Terres," or "Bad Lands," and occurring along the Missouri and its tributaries, White River, Milk River, Platte, Eau qui Court, &c. The banks and beds of these and other streams likewise contain rich treasures of fossil bones. Similar remains are to be looked for in all caves, peat bogs, alluvial soil, marl pits, fissures in rocks, and other localities throughout North America.

The floor of any cavern, if dug up and carefully examined, will generally be found to contain teeth, bones, &c. These, however similar in appearance to recent or domesticated species, should be carefully preserved.

Specimens ought to be tightly packed up in boxes, taking care that each one is wrapped up separately, in order that the angles or crystalline surfaces should not be destroyed by transportation; their value depending upon their good condition. The same precautions will be required for corals. The interstices between the specimens in the box or cask may be occupied by sawdust, sand, shavings, hay, cotton, or other soft substance. It is absolutely essential that no cavity be left in the vessel or box.

§ X. MINUTE MICROSCOPIC ORGANISMS.

It is very desirable to procure specimens, from many localities, of the various forms of microscopic animals and plants, not only on account of their intrinsic interest, but for their relation to important general questions in physical and natural science. These will almost always be found to occur in the following localities:

1. In all light colored clays or earths, as found in peat bogs, meadows, soils, &c., particularly when these are remarkably light.

2. In the mud from the bottom of lakes and pools. A small handful of this mud or of the confervoid vegetation on the bottom, if dried *without squeezing*, will retain the Diatomaceæ and Desmidieæ.

3. In the mud (dried) from the bottom and along the margins of streams in any locality. The muds from brackish and from fresh waters will differ in their contents.

4. In soil from the banks of streams. The surface and subsoils should both be collected.

5. In the soundings brought up from the bottom of the sea or lakes. These should be collected from the greatest possible depths. If an armature be used to the lead, it should be of soap rather than fatty matter, as being more readily removed from the organisms. The mud which adheres to anchors, to rocks, &c., below *high* water mark, as well as below *low* water, should also be carefully gathered.

6. In bunches of damp moss from rocks, roofs of houses, trees, about pumps, &c.

7. In the deposits in the gutters and spouting of roofs of houses.

8. In the dust which at sea collects upon the sails or decks of vessels. When not in sufficient quantity to be scraped off, enough may be ob-

tained for examination by rubbing a piece of soft clean paper over the surface affected.

Specimens of all these substances should be gathered, and, when moist, dried *without squeezing*. The quantity may vary from a few grains to an ounce, depending on the mode of transportation to be adopted. *Every specimen, as collected, should have the date, locality, depth below the surface, collector, &c., marked immediately upon the envelope.*

It is also very important to collect filterings from river, brackish, and sea waters. To do this, take a circular piece of fine chemical filtering paper, six inches, or thereabouts, in diameter, (the patent blotting paper will answer if the other cannot be procured,) and weigh it carefully in a delicate balance. Pass a quantity of the water, varying with its turbidity, from a pint to a gill, through the paper, and allow this to dry. Mark the paper or its envelope with the original weight of the paper, the amount of water passed through, date, place, &c. It is desirable to have specimens thus prepared for every locality and for every month in the year. They may be sent, as well as light packages of dried muds, &c., by mail, and should be transmitted as speedily as possible.

When the water of lakes and ponds has been rendered turbid by minute green or brown specks, these should be gathered by filtration through paper or rag, which may then be dried, or, still better, have this matter scraped off into a small vial of alcohol.

ON THE FISHES OF NEW YORK.

BY THEODORE GILL, ESQ.

New York, *April* 14, 1856.

The Secretary of the Smithsonian Institution.

Sir: Learning that you were collecting facts in behalf of the Smithsonian Institution with regard to the geographical distribution, habits, &c., of the various animals of North America, a short time since I tendered my services to you, through my friend, Mr. John G. Bell, and offered to prepare for you a brief list of the fishes observed by me in the markets of the city of New York. This offer Mr. Bell has informed me you were pleased to accept; and I have therefore drawn up such a catalogue, which I now forward to you.

For more than a year I have, with the exception of one or two interruptions of short duration, visited Fulton market at least twice a week, and occasionally Washington market.

As it is interesting to know something respecting the localities in which the observations recorded were made, although in this case not important, a short account is given of the two chief places which have been the theatres of my labors.

Fulton market is the chief wholesale fish mart of the city. The general place of traffic occupies the whole block bounded on the north by Beekman street, south by Fulton street, east by South street, and on the west by Front street. The stalls at which fish are sold by retail are situated on an elevated platform, along the north side of the general market, with the stands on both sides of a walk of moderate width. The wholesale fish market is separated from the chief market by South street, and consists of mere sheds, which front on South street, and are on the rear bounded by the East river. Here the staple fish are principally sold—cod, flounders, porgies, sea bass, &c.—while those that are only occasionally brought to the city—the exotic fishes, if I may so call them—are sold in the retail Fulton, and oftener in Washington market. In the rear of these sheds are also moored the vessels, called wells, containing the living cod, which are taken from them as occasion requires.

Washington market is situated on a corresponding block on the opposite or western side of the city, and, like the other, fronts on the south on Fulton street. A greater variety appears to be brought to this than the other market, and I have here seen most of the rarer species that are mentioned in my catalogue.

My visits to this market were commenced with the intention of investigating and recording the time of arrival and disappearance of the fishes most useful as food to man, as I was persuaded that the earliest visitors are waited for with impatience, and as soon as they arrive in our waters they are for sale, because they bring a higher price than they do in the season of greatest plenty. Their comparative abundance and other facts connected with their economical history could also be best learned here.

You will notice that I mention in my catalogue seventy-nine species in fifty-six genera and twenty families, all of which I have myself seen. I have made mention of none that have not come under my own observation; and this accounts for the absence from my list of species noticed by Dr. DeKay, and others, as being occasionally brought to the New York markets.

I have here discovered some fishes that I little expected to find sold as food, while others that I have thought to see have not yet come under my notice. These deficiencies are mostly included in the families of Scombridæ and Clupidæ. The great variety of species has surprised me. The number seen by myself nearly equals the whole number described by Dr. Storer in his report of 1839 on the fishes of Massachusetts. All of these species are occasionally found in the waters of the State of New York, and most of them are common here.

I have only walked leisurely through the market in the morning, and have not especially sought for rarities, and probably several species have been exposed for sale that have escaped my notice.

No new species, unless, perhaps, one of Pomoxis, have been seen by me. All have been described by Dr. DeKay, in his Zoology of New York, except the Pomoxis Esox nobilior, Th., and the Labrus appendix of Dr. Mitchell, which DeKay did not describe from personal observation, but merely abstracted the notice of it given by Dr. Mitchell in the second volume of the American Monthly Magazine (1818),

and transferred it to its proper genus Pomotis. I have found it to be quite common here during the colder months of the year.

It is a very difficult matter to obtain any satisfactory information respecting the localities in and the circumstance under which the various fishes are caught. The dealers of the markets purchase the fishes from others. The true fishermen, whose business is restricted to the catching of them, and having but little of that intelligent curiosity which would lead them to inquire into the habits and the peculiarities of the animals which they make it their employment to buy and sell, do not ask any questions concerning them, and cannot therefore dispense any knowledge to others; with them it is sufficient to know in what State or on what coast the fish is caught, and even in this respect we cannot be certain that the information is always correct. The exact locality is rarely known. I have therefore seldom particularized the places in which they are caught.

My observations do not always agree in all respects with the remarks made by the author of the New York Fauna respecting the appearance and departure of the migratory fishes occurring on the coast of this State.

For the sake of convenience the classification, and generally the nomenclature used by Dr. DeKay in his New York Fauna, is adopted. In those cases where the species noticed are placed in different genera from those to which they were referred by their original describers, I have enclosed the name of the author of the specific name in parentheses, and that of the naturalist who transferred it to the genus adopted in the catalogue after it in open space. For convenience of reference, I have mentioned the pages where the species are described in Dr. DeKay's New York Fauna.

I am fully aware of the imperfectness of this catalogue, and had hoped to have made a more full one, but various causes have deterred at present. I may, perhaps, at some future time, make out a more complete and extended list, in the hope, however, that this will prove of some small service to you.

DESCRIPTIVE LIST OF FISHES OF THE NEW YORK MARKET.

PERCIDAE, Cuv.

1. Perca flavescens (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 3, fig. 1.

The yellow perch is sent to the markets in considerable numbers and quite regularly from the beginning of September till the end of April. It is sold at from eight to ten cents per pound.

This species, as far as I can learn, is not very abundant in any of the streams in the vicinity of this city.

2. Labrax lineatus, (*Bloch*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 7, fig. 3.

The striped bass is common with us during the whole year, but is brought to market in finer condition, as well as in larger quantities, in the winter and earlier spring months; I have then seen individuals

weighing as much as seventy pounds. In April, young fishes, measuring from two to four inches, are also brought, which have several narrow, indistinct, transverse bands, as described in the notice of the fishes of Beesley's Point.

I have seen a specimen that I considered as only a variety of this species, agreeing in its marking with the L. notatus of Sir John Richardson, as noticed by Dr. DeKay. In form and every other particular it resembled the common bass.

The striped bass is one of the most esteemed fishes found in our waters, and sells readily at from ten to twelve cents a pound, and it occasionally brings even eighteen cents. It is sent to market in considerable numbers from the shores of Long Island, and many are also caught on the New Jersey side of New York bay, a short distance below Jersey city.

3. Labrax rufus, (*Mit.*,) *DeKay.*

DeKay, N. Y. Fauna, p. 9, fig. 7.

This species is found in our markets from the first of September till as late as the end of June, but in the greatest numbers in the early spring. The average size is less than ten inches long. It is sold at from six to eight cents, and occasionally at ten cents per pound.

This fish is generally known to the fisherman under the simple name of "Perch;" the Perca flavescens being distinguished as the "Yellow Perch."

Fishes are occasionally brought which are a shade lighter in their color than the general color of this species, but they agree in every other respect, even to the most minute points, with the L. rufus.

4. Lucioperca Americana, (*Cuv. and Val.*)

DeKay, N. Y. Fauna, p. 17, fig. 163.

This percoid is occasionally sent to our markets from the first of September till towards the middle of spring. It is called by the fishermen "Lake Pike," and by some "*Maskalonge.*"

This and many other species found in the interior of the State of New York, are packed in saw dust and sent to this city by express. I am informed that most of them are caught in the small lakes of central New York, Cayuga, &c.

5. Serranus erythrogaster, DeKay.

DeKay, N. Y. Fauna, p. 21, fig. 52.

This species is sometimes sent to our market from Key West and the reefs of Florida in May and the summer months. I have never seen more than two or three exposed for sale at a single time. It appears to be considerably esteemed and is sold at from twelve to fifteen cents per pound.

This fish is generally called by the fishermen "red snapper." I have been told by them that it takes the hook in the same manner as the Black fish, (*Tautoga americana*,) and that it otherwise resembles that labroid in its habits. How much reliance is to be placed on this information I do not know.

6. Centropristes nigricans, (*Bloch*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 24, fig. 6.

This fish is generally known by our citizens as the "sea bass." It is first brought to market towards the latter part of April or the beginning of May, and continues to be exposed for sale till the middle of October. A very few are brought to the end of that month and even later, but none are to be seen in winter. It is a delicious fish, but being very common does not sell for more than eight to twelve cents per pound.

7. Grystes fasciatus, (*Les.*) *Agassiz.*

Huro nigricans, Cuv. and Val. DeKay, N. Y. Fauna, p. 15, fig. 224. Centrarchus fasciatus, ib. p. 28, fig. 8.

The black bass is rather common—more so than any other of the lacustrine species—in our markets during the milder parts of winter and the first half of spring. I have been informed that they are sent from Lakes Erie and Ontario, as well as Lake Cayuga, and that a few are caught in the Hudson river, where they have been introduced since the opening of the great Erie canal. They appear to be much esteemed by our citizens and are generally sold at twelve cents per pound. They are called by our fishermen "lake bass."

8. Ambloplites æneus, (*Les.*) *Agassiz.*

Centrarchus æneus, Cuv. and Val., DeKay, N. Y. Fauna, p. 27, fig. 4.

This species had not, as late as last fall, received any popular name from the fishermen. It is brought from the same localities, according to the fish dealers, as the black bass, but not in so large numbers. It is most common during the early part of spring, when it brings about ten cents per pound.

9. Pomoxis.

A species of the genus Pomoxis, of Rafinesque, as characterized by Professor Agassiz, is occasionally brought to the New York markets with the two preceding, and from the same locality. I have only seen Rafinesque's description of the P. annularis, Raf., of the Ohio river in the first volume of the Transactions of the Philadelphia Academy of Natural Sciences, and the brief notice of the Centrarchus hexacanthus of Cuv. and Val., given by Dr. DeKay in his N. Y. Fauna, and from both of these it appears to differ—from the P. annularis widely if Rafinesque's description and figure are correct. Professor Agassiz, in his "Notice of the Fishes of the Tennessee River," in the American Journal, vol. XVII, p. 298, in his remarks on the geographical distribution of the genus, states that he has received a species "from the western part of New York," and the species brought to this market is probably identical with his. As I have never seen his description, however, I will give a short notice of it.

The body is very much compressed; the greatest depth contained little less than twice in its total length. The dorsal and abdominal

outlines are nearly equally convex. The head is nearly a third of the total length of the body, and there is a considerable depression immediately over the eyes, which causes the snout to appear turned up. The mouth is large, and the maxillary bones reach a point vertical to the posterior borders of the eyes. The eyes are a third nearer the snout than the opercular spine, and are large, their diameter being to the length of the head as two to nine. The lateral line runs nearly parallel with the dorsal outline. The dorsal fin commences nearer the snout, and is supported anteriorly by seven spinous rays. The first spine is very low, and, in a specimen seven inches long, was little more than one-sixth of an inch in length, and about half the length of the second; from the latter they rapidly but regularly increase in size to the seventh, which is about an inch long. The anal fin commences under the fourth spinous ray of the dorsal, and seven of its soft rays extend beyond the posterior part of that fin. The spines are in nearly the same proportion to each other as those of the dorsal fin. The spines of both fins are all curved slightly backwards.

D. VII, 16. A. VI, 16. P. 13. V. 15. C. $17\frac{2}{2}$?

The general color of the body is a dark bronze yellow, shaded with green and with golden reflection above, and many of the scales are darker on the margins. The dorsal and anal fins are colored with six or seven rows of round, yellowish spots. most of which cover the rays as well as the connecting membrane. There are fewer of these spots on the spinous parts of both fins. The pupils are of an intense dark blue, and the irides a dark straw yellow.

This description was drawn from a specimen about seven inches in length, and is, perhaps, in some respects defective, as I was called off before I was able to finish my notes, and have not been able to procure another since. The color is drawn entirely from memory, but is, I think, correct.

This percoid is not often brought to market, but when exposed for sale it is mingled with the two following species:

10. Pomotis appendix, (*Mit.*) *DeKay*.

DeKay, N. Y. Fauna, p. 32.

This species is brought to market in considerable numbers in winter and spring from Cayuga Lake, &c., It is a matter of surprise that Dr. DeKay never saw this species, as I have been told that it is very common in all the lakes of central New York. It reaches a much larger size than the common sunfish.

11. Pomotis vulgaris, *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 31, fig. 166.

This handsome sunfish is sent to market from the same places as the preceeding, according to the fishermen, although it is very common in almost all of the neighboring streams. This and the two former species are sold at from eight to ten cents per pound. Some of the fishermen are under a singular error in regard to Pomoxis and Pomotis. They believe them to constitute a single species, of which Pomoxis is the male, and Pomotis vulgaris and Pomotis appendix

females. It is only necessary to revert to the different geographical areas in which the various species are found to be at once convinced of the absurdity of this opinion.

TRIGLIDAE, (Cuv.) DeKay.

12. PRIONOTUS LINEATUS, (*Mit*) *DeKay.*

DEKAY, N. Y. Fauna, p. 45, fig. 12.

The "Robin," "Sea Robin," and flying fish, as this species is indifferently called by our fishermen, is occasionally brought to the markets in the month of May. It does not appear to be much esteemed, and is eaten from necessity rather than from choice. They generally sell for about twelve cents a dozen. The average size is about twelve inches long.

13. SEBASTES NOVREGICUS, (*Muller*) *Cuv. and Val.*

DEKAY, N. Y. Fauna, p. 60, fig. 11.

I observed a few specimens of this triglоid in the third week of February of this year. The man in whose possession they were called them "Red Snappers," the same name which they apply to the Serranus morio, DeKay, and furthermore told me that they were sent from *Charleston!* They agreed with the description and figure given of the Sebastes norvegicus by DeKay, who also gives "snapper," as one of the popular names by which they are known. May not this be the species to which the "intelligent fisherman" alluded, who informed Dr. DeKay that the Serranus erythrogaster, DeKay, "is occasionally, but very rarely, taken off our coast?" The fishmonger, on whose stand the species in question was exposed, is the only one in whose possession I have seen the Serranus erythrogaster.

SCLÆNIDÆ, Cuv.

14. LEIOSTOMUS OBLIQUUS, (*Mit.*) *DeKay.*

DEKAY, N Y. Fauna, p. 69, fig. 195.

The "Lafayette" appears to be rather late in their arrival on the coast of this State. Last year I saw none in market until the first of September. After that they were brought in greater or less numbers until nearly the end of October. Most of those that I saw [illegible] under six inches in length. I asked the [illegible] th[illegible] usually visit us earlier; they [illegible] Fauna, p. 106, fig 27. this year as usual. [illegible] this species were exposed for sale last year at [illegible]es in the months of August and September.

26. CYBIUM MACULATUM, (*Mit.*) *Cuv. and Val.*

DEKAY, N. Y. Fauna, p. 108, fig. 232.

This species, known to our citizens as the "Spanish mackerel," is brought to market during the same months as the preceding species. It is not very common.

to this fish, which is, I think, too low. Ten inches would be nearer the average length of those brought to market last year.

The weak fish is seldom sold at more than six or eight cents per pound.

16. Corvina ocellata, (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 70, fig. 61.

This scienoid is known to our fishermen under the name of "red fish" and sometimes "branded drum." It is seldom sold in the New York markets. I saw a few in the month of February of the present year which, I was informed by the fishermen, were sent from Charleston, S. C. Fifteen cents per pound were asked for them.

I have never seen the Corvina argyroleuca, Cuv. and Val., in the markets.

17. Umbrina alburnus, (*Lin.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 78, fig. 20.

This most excellent fish is brought to market during almost the same periods as the weak fish. It appears, however, to be slightly later in its arrival on our coast, for last summer the weak fish had been brought to market two weeks before I saw any king fish. The king fish is not quite as abundant as the weak fish. It hardly brings a price commensurate with its good qualities, being rarely more than twelve cents per pound, and often not over ten cents.

18. Lobotes surinamensis.

DeKay, N. Y. Fauna, p. 88, fig. 49.

I saw a single specimen of this species in Fulton market last year, which remained exposed on the stall from the thirtieth of August till the sixth of September. It did not seem to be known. The owner called it "flasher;" why it was so named, I was unable to learn. The individual on sale was about fifteen inches in length, and a dollar was demanded for it.

19. Pogonias chromis, (*Lin.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 80.

larger ... "dru..." ... brought to market last year in the early part ... of September. These are the only ... them. Most of them

11. Pomotis vulgaris,

DeKay, N. Y. Fauna, p. 31, fig.

This handsome sunfish is sent to market from the same ... the preceeding, according to the fishermen, although it is very common in almost all of the neighboring streams. This and the two former species are sold at from eight to ten cents per pound. Some of the fishermen are under a singular error in regard to Pomoxis and Pomotis. They believe them to constitute a single species, of which Pomoxis is the male, and Pomotis vulgaris and Pomotis appendix

rather more frequently and abundantly in June—but rarely in any great numbers. I have never seen more than thirty at a single time, and it is seldom that more than five or six are seen. It is very much esteemed by the New Yorkers and brings a high price.

I do not recollect having seen the sand porgee (*Sargus arenosus*, *DeKay*,) in market.

21. Pagrus argyrops.

DeKay, N. Y. Fauna, p. 95, fig. 25.

The porgee is the most common fish of the summer months, and our markets are supplied with them to excess. Owing to this abundance, although an excellent article of food, they are sold very cheap, three to six cents being the retail price per pound.

They were brought last year towards the end of April, and were as abundant on the first day that I saw them in market as at any subsequent period, none appearing forerunners of larger bands, as appears to be the case with some of our summer visitants. Unlike their arrival, however, they disappear by degrees, and become fewer in number as the autumn advances. Some linger till about the end of November.

SCOMBRIDÆ, Cuv.

22. Scomber vernalis, (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 101, fig. 34.

Brought to market in the months of May, June, and July, and sold for ten or twelve cents a pound.

23. Scomber grex, (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 103, fig. 32.

Two or three months intervene between the time that the former species disappears from the markets and the one in question is first brought here.

24. Scomber colias, *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 104, fig. 33.

This species does not appear to be very abundant here. I saw but very few last year during the months of July and August.

25. Pelamys sarda, (*Bloch*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 106, fig 27.

A few specimens of this species were exposed for sale last year at different times in the months of August and September.

26. Cybium maculatum, (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 108, fig. 232.

This species, known to our citizens as the "Spanish mackerel," is brought to market during the same months as the preceding species. It is not very common.

27. Palinurus perciformis, (*Mit.*) *De Kay.*

DeKay, N. Y. Fauna, p. 118, fig. 75.

The only occasion on which I have seen this species in market was on the 3d of September, 1855, when some twenty or thirty were exposed on one of the stalls.

28. Caranx chrysos, (*Mit.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 121, fig. 85.

I only saw a very few specimens of this species in Washington market, in the month of October of last year.

29. Temnodon saltator, (*Lin.*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 130, fig. 81.

The blue fish are very common in our markets during summer and autumn, and are sold at from six to eight cents per pound. They arrived last year on our coasts towards the last of May, and remained till November.

30. Coryphæna globiceps, (*Mit.*) *De Kay.*

DeKay, N. Y. Fauna, p. 132, fig. 29.

I saw a single specimen of this Scombroid considerably over two feet long, in Washington market, on the 24th of August, 1855.

31. Rhombus triacanthus, (*Peck*) *De Kay.*

DeKay, N. Y. Fauna, p. 137, fig. 80.

This fish is brought to market in September, October, and November. It is called by the fishermen "harvest fish," and "butter fish."

MUGILIDÆ, Cuv.

32. Mugil albula, *Lin.*

DeKay, N. Y. Fauna, (fi.) p. 146.

Mullets are exposed for sale in the markets during February and the spring months, principally in February and March, but in no very great numbers.

GOBIDÆ, Cuv.

33. Zoarces anguillaris, (*Peck*) *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 155, fig. 45.

34. Zoarces fimbriatus, *Cuv. and Val.*

DeKay, N. Y. Fauna, p. 156, fig. 44.

Both of these fishes are occasionally brought to the markets in the months of March and April. The former is the more common of the two. They do not appear to be much esteemed, probably on account of the repulsiveness of their appearance.

LABRIDÆ, Cuv.

35. Ctenolabrus ceruleus, (*Mit*,)
DeKay, N. Y. Fauna, p. 179, fig. 93.

36. Ctenolabrus uninotatus, (*Mit.*)
DeKay, N. Y. Fauna, p. 174, fig. 90.

Both of these species, called by our fishermen under the common name of "Bergalls," are brought to market in spring and autumn. The C. ceruleus is the most common. Some are exposed for sale in a perfect condition, but most of them are skinned, gutted, and the head cut off, and strung on sticks, &c., through the middle of the body in numbers of about two dozen.

37. Tautoga americana, (*Schn.*) *Cuv. and Val.*
DeKay, N. Y. Fauna, p. 175, fig. 39.

We have the black fish with us during almost the entire year, but it appears to be comparatively rare in winter, becoming more abundant towards the commencement of April.

SILURIDÆ, Cuv.

38. Pimelodus catus, (*Lin.*) *Cuv. and Val.*
DeKay, N. Y. Fauna, p. 189, fig. 119.

Catfish are brought to market in small quantities in the spring months. They are usually sold at about eight cents per pound.

CYPRINIDÆ, Cuv.

39. Cyprinus carpio, *Lin.*

I saw several European carp in the Washington market last year, in the month of April. The person on whose stand they were exposed informed me that they were caught in the Hudson river; this was all I could learn respecting them.

40. Leucosomus americanus, *Girard.*

Abramis versicolor, DeKay, N. Y. Fauna, p. 191, fig. 103.

This species is very rarely brought, and rather by accident, with sun-fish and suckers, caught near this city.

41. Catastomus oblongus, (*Mit.*) *Les.*

DeKay, N. Y. Fauna, fi. p. 193, fig. 136.

Occasionally brought to market in winter and early in spring, I have seen the adult male in winter dress, (*C. oblongus*,) the same in his nuptial dress (*C. tuberculatus Les.*) and the young male (*C. gibbosus*, *Les.*) all in market at the same time. They are called by our fishermen, chub, chub-suckers, and often by the simple name of sucker.

42. Catastomus communis, *Les.*

DeKay, N. Y. Fauna, fi. p. 196, fig. 100.

This species is brought to market in autumn, winter, and spring. It is simply called "sucker." The fishermen have, however, no clear perception of the difference between this species and the *C. oblongus.* None of our species of catastomus are held in much repute. The species brought to market are sold at four cents generally, and more rarely at six cents per pound. The larger specimens are sometimes called by the fishermen, "Fresh water pollack."

CYPRINODONTES, Agassiz.

43. Fundulus zebra, DeKay, N. Y. F. fi. p. 218.

44. Fundulus viridescens, (*Mit.*,) DeKay, N. Y. F., p. 217, fig. 99.

45. Hydrargyra flavula, (*Mit.*) Storer.

Fondulus fasciatus, DeKay, N. Y. Fauna, fi. p. 216, fig. 98.

A considerable number of these species were brought to market in the early part of April, last year, and were sold by the measure at twelve cents per quart. I perceive that in the notice of the fishes of the New Jersey coast you are inclined to regard the *F. viridiscens* of DeKay, as merely the female of *F. zebra*, DeKay.

ESOCIDÆ, Cuv.

46. Esox reticulatus, *Les.*

DeKay, N. Y. Fauna, fi. p. 223, fig. 107.

The pickerel appears in our markets in the beginning of the autumn. and thenceforth continues to be brought till spring has far advanced. They are worth from twelve to fifteen cents a pound.

47. Esox fasciatus, *DeKay.*

DeKay, N. Y. Fauna, fi. p. 224, fig. 110.

Brought in less numbers and more irregularly than the preceeding.

48. Esox estor, (*Les.*) *Thompson.*

DeKay, N. Y. Fauna, f. p. 222.

This lacustrine species is frequently to be seen in our markets in the fall and spring months, and when the weather is mild and the communication with the "lakes" uninterrupted, it is also brought in winter. It brings from twelve to fifteen cents per pound.

49 Esox nobilior, *Thompson.*

Quite a number of this excellent species was brought to market in February of this year. It appears to be much esteemed and is sold at about eighteen cents per pound.

50. BELONE TRUNCATA, *Les.*

DEKAY, N. Y. Fauna, p. 227, fig. 112.

This fish does not appear to be very common here. During the months of September and October, 1855, several dozen were brought to market. They were called by the fishmongers "bill fish."

SALMONIDÆ, Cuv.

51. SALMO FONTINALIS, *Mit.*

DEKAY, N. Y. Fauna, fi. p. 235, fig. 120.

The common trout is sent to market from Long Island from November to April; more abundantly in spring. In the markets they are sold at a very high price: from thirty-seven to fifty cents per pound. Occasionally they are exposed for sale in the streets—principally Wall street—at twenty-five cents a pound.

52. SALMO CONFINIS, *DeKay.*

DEKAY, N. Y. Fauna, p. 238, fig. 123.

The lake trout is sometimes brought in considerable numbers from northern and western New York during the autumn, winter, and spring months. It is much less relished than the common brook trout.

SALMO SALAR, *Lin.*

DEKAY, N. Y. Fauna, p. 241, fig. 132.

Sent in limited quantity during the same months as the preceding, from Nova Scotia.

OSMERUS VIRIDISCENS, *Les.*

DEKAY, N. Y. Fauna, p. 243, fig. 124.

The smelt is also one of our most esteemed fishes, and is sold at a price varying from twelve to twenty-five cents a pound. The price appears to be very fluctuating, thus in the latter part of February, they brought twenty-two cents per pound; on the first of April, twelve cents was all demanded; they were at least as common in the preceeding month as in April.

COREGONUS ALBUS, *Les.*

DEKAY, N. Y. Fauna, p. 247, fig. 198.

The white fish of the northern lakes is brought to the New York markets at considerable intervals of time, and in small numbers in spring and fall. I have seen them in May, September, and October.

CLUPIDÆ, Cuv.

54. Clupea elongata, *Les.*

DeKay, N. Y. Fauna, f. p. 250.

A species of clupea, which agreed in most respects with the *C. elongata*, *Les.*, as described by that naturalist, was exposed in our markets in quite large numbers during the months of March and April. The market men called them "English herring;" one of them told me they were sent from Nova Scotia, and another, from St. John's, New Brunswick. They were sold at eight cents a pound. Dr. DeKay has committed a great error in his description of the species.

55. Alosa praestabilis, *DeKay.*

DeKay, N. Y. Fauna, fi. p. 255, fig. 41.

The shad is sent to our city from Charleston (S. C.) in considerable numbers as early as the latter part of January and February, but does not arrive on our own coast until March. An average sized fish sells in early spring at seventy-five cents to a dollar, and sometimes even more; but as the season advances, and they become more plenty, the price is reduced to about twenty-five cents each.

56. Alosa tyrannus, (*Latrobe*) *DeKay.*

DeKay, N. Y. Fauna, fi. p. 258, fig. 38.

Sent to market occasionally in spring.

57. Alosa menhaden, (*Mit.*) *Storer.*

DeKay, N. Y. Fauna, p. 259, fig. 60.

Mossbunkers appear in the markets in the fall months; but in no great quantity.

58. Alosa mattowacca, (*Mit.*) *De Kay.*

DeKay, N. Y. Fauna, fi. p. 260, fig. 127.

The fall herring is rather common in autumn and winter. A few appear towards the end of summer.

COELACANTHS, Agassiz.

59. Amia occidentalis, *DeKay.*

DeKay, N. Fauna, p. 269, fig. 125.

A single specimen of this ganoid, about two feet long, was offered for sale in Washington market on the fifteenth of May, 1855. I could learn nothing in regard to it from the fishmonger on whose stand it was. It appeared to be totally unknown to him, and he could not even tell me the name of it.

GADIDÆ, Cuv.

60. MORRHUA AMERICANA, *Storer.*

DEKAY, N. Y. Fauna, p. 274, fig. 140.

The universally known cod is the most abundant of fishes during the entire year. The price is more uniform than that of most of our fishes, and is hardly ever over six or less than five cents a pound.

61. MORRHUA PRUINOSA, (*Mit.*) *DeKay.*

N. Y. Fauna, fi., p. 278, fig. 142.

Brought to market in large numbers in the fall and winter months and the greater part of spring. It is sold from six to ten cents a pound.

62. MORRHUA ÆGLIFINA, (*Lin.*) *Cuv.*

DEKAY, N. Y. Fauna, p. 279, fig. 138.

Less common than its congener, the cod, and not brought so constantly to market; in the autumn and first months of winter it is comparatively rare. Although by many esteemed as inferior to the cod, it is generally sold for the same price and occasionally higher.

63. MERLANGUS CARBONARIUS, (*Lin.*,) *Cuv.*, DE KAY, N. Y. Fauna. p. 287, fi. 144.

64. MERLANGUS PURPUREUS, (*Mit.*) *Storer*, N. Y. Fauna, p. 286, fi. 147.

Both species are brought to the New York markets in September, October, and November. The M. purpureus is rarer of the two.

65. PHYCIS AMERICANUS, (*Schn.*) *Storer.*

This gadoid was brought to market this year in considerable numbers. I have also seen a few on the last of May. It attains a large size apparently, as I have never seen one in market less than two feet long, and generally they are much larger. To the fisherman it is known as the hake or codling.

66. PHYCIS PUNCTATUS, (*Mit.*) *Richardson.*

DEKAY, N. Y. Fauna, p. 292, fig. 149.

This phycis appears to be a rare species on the coast of New York, and is seldom brought to market. I saw a few last year on different days of October. They were sold under the simple name of "Ling."

PLANIDÆ, Cuvier.

67. HIPPOGLOSSUS VULGARIS, *Cuv.*

DEKAY, N. Y. Fauna, f. p. 294, fig. 157.

The halibut is brought to market all the year. It is cut up in steaks and sold at a price varying from ten to fifteen cents a pound.

68. Platessa plana, (*Mit.*) *Storer.*

DeKay, N. Y. Fauna, p. fig.

This is the most common species of flounder that is brought to the city markets in the winter and spring months. It is seldom sold at a higher price than eight to ten cents per pound.

Flounders are chiefly sold by the weight; occasionally they are strung through the branchial apertures on twigs and nominally sold by the bunch.

69. Platessa pusilla, *DeKay.*

DeKay, N. Y. Fauna, f. p. 296, fig. 153.

I have rarely seen this species in market. When brought to market they are always mingled with the P. plana.

70. Platessa dentata, (*Mit.*,) *Storer.*

DeKay, N. Y. Fauna, f. p. 298.

71. Platessa ocellaris, *DeKay.*

DeKay, N. Y. Fauna, f. p. 300, fig. 152.

The common flounders of the summer months.

72. Platessa oblonga, (*Mit.*) *DeKay.*

DeKay, N. Y. Fauna, p. 299, fig. 156.

This species is most common in the autumn months and the early part of winter.

In August of last year I observed a specimen of this species with the dark side doubled. The dextral was as dark as the sinistral side to within a short distance of the opercle; the brown color then abruptly ceased, following the curve of the opercle, and the remainder of the inferior surface of the body and the head were of the usual color.

73. Pleuronectes maculatus, *Mit.*

DeKay, N. Y. Fauna, f. p. 301, fig. 151.

This fish is not often brought to the New York markets. I only saw a few last year in the early part of May.

74. Achirus mollis, (*Mit.*,) *Cuv.*

DeKay, N. Y. Fauna, f. p. 303, fig. 159.

I have never seen this species in either Washington or Fulton markets; but last year, on the last of February, I saw a single specimen on the fish stall of a private market in the city.

ANGUILLIDÆ, Cuvier.

75. ANGUILLA TENUIROSTRIS, *DeKay.*

DEKAY, N. Y. Fauna, f. p. 310, fig. 173.

The common eel is brought to market in almost every month of the year. Few are sold entire; most of them are exposed cleaned, skinned, and with the head cut off. In this state they are generally sold at twelve cents a pound.

STURIONES.

76. ACIPENSER OXYRHYNCHUS, *Mit.*

DEKAY, N. Y. Fauna, fi. p. 346, fig. 189.

In the spring young specimens of this sturgeon, agreeing with the description and figure of Dr. De Kay, are occasionally brought to market. These young range from ten inches to two feet in length. Larger individuals are cut into transverse sections or steaks and sold by the pound. Whether these larger fish are the Acipenser oxyrhyncus of Mit., or some other species, I am at present unable to say with confidence, as I have not examined an unmutilated specimen. I have been told they are occasionally brought entire, and even alive, into the markets, and will, therefore, probably soon have an opportunity of examining one.

RAIADAE.

77. RAIA DIAPHANES, *Mit.*

DEKAY, N. Y. Fauna, fi. p. 366, fig. 218.

This species is occasionally brought to market in winter and spring, and sold under the name of "French skate."

78. RAIA LÆVIS, *Mit.*

DEKAY, N. Y. Fauna, f. p. 370.

This ray is also brought to market occasionally in winter, but more seldom than the preceding.

Only the fleshy pectoral fins of this species are exposed for sale, the head and tail being always cut off. The Raia diaphanes, on the contrary, is generally to be seen entire, and is only cut up at the desire of the purchaser. Neither of the species is much valued as food.

PETROMYZONIDAE.

79. PETROMYZON AMERICANUS, *Les.*

DEKAY, N. Y. Fauna, f. p. 379, fig. 216.

The sea lamprey rarely appears in our market, and never in any great quantity. I have seen them in small numbers in the month of April. Specimens two feet long, living and writhing on the stalls, [illegible] then been offered at twelve to eighteen cents each. This hardly [illegible] statement made by Dr. DeKay respecting the estimation [illegible] they are held by the epicures.

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ngle speci-

ANCIENT INDIAN REMAINS, NEAR PRESCOTT, C. W.

BY W. E. GUEST.

One of the oft reiterated assertions of foreigners on visiting our country as they pass rapidly from the Atlantic to the lakes, and from the lakes to where the "Father of Waters rolls his flood," is that "the country is too new; that it has no ancient time-marked monuments, no ivy-robed ruins with gray turrets pointing to the distant past, or storied urns rich with the records of human greatness to serve as models for the present."

A greater error, perhaps, was never committed. Hundreds, aye thousands of years before the white man's foot had pressed the soil of the New World, there lived and flourished a race of men who called this continent their home. Had they a written history, what deeds of chivalry might we not peruse; what tales of forest "Agamemnons" and unknown "kings of men" Alas! for their glory, their ardor, and their pride!

"They have all passed away,
That noble race and brave,
Their light canoes have vanished
From oft the crested wave.
——————— but
Their name is on your waters,
You may not wash it out!"

Many are the traces of their existence that lie widely scattered over the surface of the country, such as burial grounds, places of sacrifice or defence, and earthern mounds of various shapes and sizes; the latter class being so numerous that as many as two hundred and fifty have been examined and surveyed in the State of New York alone. All these interesting relics, however, like the remnant of the race to which they belong, are fast disappearing before the progress of civilization, and will probably in time be entirely obliterated; a fact calling for energetic exploration and earnest investigation while yet the opportunity is offered.

Having been informed of the existence of some ancient Indian works in the vicinity of Prescott, C. W., I made a visit to one of great interest on July 17, 1854. The work in question is situated in the township of Augusta, about eight miles and a half northwest of Prescott, on a farm occupied by Mr. Tarp. Jas. Keeler, esq., who resides within a mile of the works, accompanied me, and to him I am indebted for much valuable information not only respecting this locality, but also of a similar work in the town of Edwardsburgh, near Spencerville, about one mile and a half in a northerly direction.

This ancient work in Augusta is about eighty rods in length, its greatest width twenty rods. The westerly part has a half moon embankment, extending some ten rods across a neck of land, terminating

to the north in a swamp, and to the southwest near the edge of a creek. It has three openings, which are from twenty to twenty-five feet wide. Upon the embankments there is a pine stump four and a half feet across, five feet from the ground, with its root extending over the embankment, showing that it has grown there since the erection of the earth work.

This place, from present appearances, was doubtless the only one approachable by land, and a rise of a few feet of water almost surrounding the work, would insulate it and add very much to its defence. The eastern and southeastern portions where there are tumuli, and where, from appearances, the inhabitants resided, is from fifteen to eighteen feet above, and descends abruptly to the now swampy grounds. On the north is a large tamarack swamp, which is said to contain about

Fig. 1.

VIEW OF THE MOUNDS AT PRESCOTT.

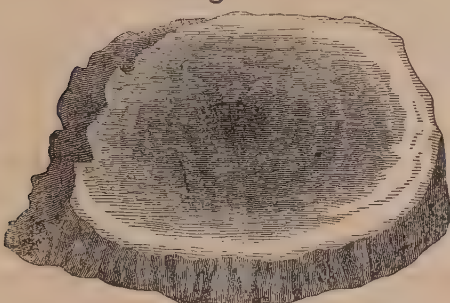
twelve thousand acres. The "Nation" river is about a mile to the northeast, and the intervening land is low, while the southeast and south ground rises gently at a distance of fifty or eighty rods. The soil on this table land is rich, and at every step evidences are beheld

of its having been once thickly inhabited. The ground is strewed with broken pieces of earthen ware, and hollow and smooth pieces of stone, doubtless used for culinary purposes. The timber, which was mostly pine, is, except a small portion on the westerly part all cut down, indeed the original forest is entirely gone within the enclosure proper.

It will be necessary to consult the diagram to obtain a proper idea of the locality of the mounds and embankments. The tumuli are four in number, situate at the corners of a parallelogram, containing between one and two acres of ground, within which are to be seen the regular streets and lines of a village; outside of the mounds, on three sides are double lines of circumvallation; on the fourth side, which faces the southeast side, there is but one.—(See fig. 1.)

The elevations of ground which we have called tumuli, or mounds, are at present but slightly raised above the general level—say from two to four feet. On opening these they were found to be composed of earth, charcoal and ashes; and contained human bones, pointed bones from the leg of the deer, horns and skulls of the same animals, human skulls, and bones of the beaver, muscle shells of the genus Unio, such as are now found on the shores of the St. Lawrence river, and which were doubtless used as food, since they are very common about such mounds. With these were great quantities of earthenware, some of which was of the most elaborate workmanship. On the surface of the ground were scattered numbers of smoothed pieces of quartz and sandstones. One stone or boulder of hornblendic gneiss (fig. 2,) was hollowed out into a cavity of sixteen inches in length, twelve, in breadth, and four and a half inches in depth; had it not been broken off at one end it would probably have held a gallon.

Fig. 2.



EXCAVATED STONE.

On the 3d of August I revisited this place with some friends, and, with the aid of two laborers, we exhumed a large variety of bones, bone points, broken pieces of pottery, earthenware, pipes, needles, and a part of the tooth of a walrus, (fig. 3.) This had holes drilled through it as though it had been used for ornament.

Fig.

WALRUS TOOTH.

I then proceeded to the work, previously mentioned, in Edwardsburgh, near Spencerville, about half a mile west of the village, on an elevated piece of ground. This is well chosen for defence—overlooking

the surrounding country to a great distance. Here (fig. 4) we traced the faint lines in part and bolder in other parts of an embankment in the shape of a moccasined foot, the heel pointing to the south and

Fig. 4.

ANCIENT WORK NEAR SPENCERVILLE.

the toes north, enclosing about three and a half acres of ground. It is situated on the front of the west half of lot twenty-seven, seventh concession in Edwardsburgh, on the farm of John McDonald, esq., who, with Messrs. Imrie and Mitchell, kindly accompanied us, and, from their acquaintance with the locality, aided very much in exploring the embankment, which was in some places almost obliterated.

This enclosure has been cultivated for some years, and at the time of the visit was mostly covered with luxuriant crops, so that we were unable to make excavations. Some parts of the embankments are from two to three feet high; on these, also, are some enormous pine stumps, one of which was nearly five feet across its top.

Some few pieces of pottery were obtained here, similar to those found in Augusta; also pieces of clay pipes, one of them richly ornamented, and a stone implement sharpened to a point, which was doubtless used

Fig. 5

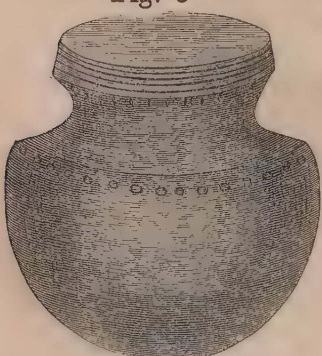
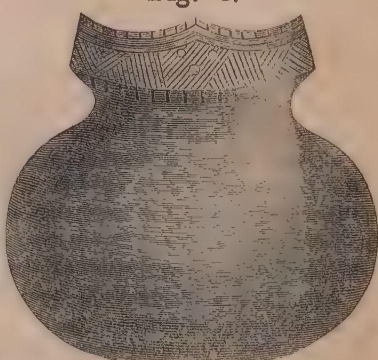


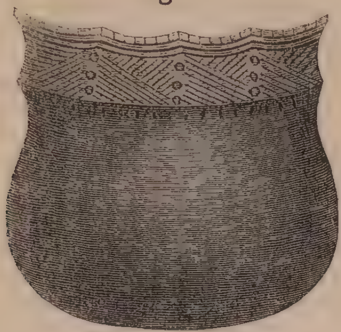
Fig. 6.



for dressing skins. There were also human bones scattered over the field which the plough had thrown up. The "terra cotta" found here is elaborate in its workmanship, and is as hard as the stone-

ware of the present day. It seems to be composed of quartz pounded up and mixed with clay, which adds to its hardness; and as to beauty of shape, some of the restored articles (see figs. 5, 6 and 7) will at

Fig. 7.



least compare favorably with any form of Indian manufacture hitherto discovered. These vessels have been found from four to eight and three-quarter inches inside. We likewise found a few rounded pieces of pottery in the shape of coin, (figs. 8 and 9,) about the size of a quarter

Fig. 8.

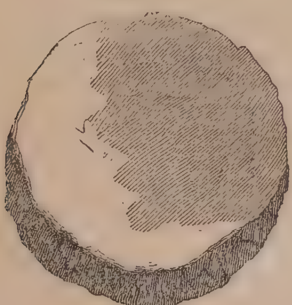
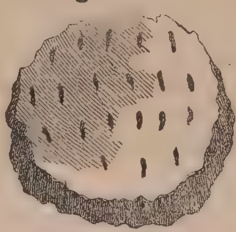


Fig. 9.



FRAGMENTS OF POTTERY ARTIFICIALLY ROUNDED.

of a dollar and less, as well as some small rounded pieces of steatite, with holes through the centre, (fig. 10.) There was one beautifully polished bone needle, about five inches long, with an eye rudely perforated, and a piece of ivory in the shape of a knife (fig. 11), made of a shark's tooth,

Fig. 10.

PREFORATED FRAGMENT OF STEATITE.

Fig. 11.

which had some marks upon it transversely, by which the owner evidently intended to identify it. In a subsequent visit to these remains we obtained an earthen pipe complete, and a piece of a human skull polished and with several notches cut in its edge. The bowl of a pipe was shown us with a face strongly characteristic of the western aborigines.

The great size of the trees, the stumps of which remain upon the embankments, are, in some degree, chronological evidence of the long time that has elapsed since these monuments were erected; and the fact of the bones of the walrus and shark being found, shows their acquaintance and communication with the sea, while the entire absence of stone pipes and arrow heads of the same material, (which belong comparatively to a more recent age,) as well as the entire deficiency of metals, or anything European to connect them with the western or southern tribes of Indians, and the significant fact that no remains of this kind have been found upon the borders of the St. Lawrence, but that they are *always* situated upon terraces from one hundred and twenty feet (the height of these) to two hundred feet above the present level of the water, is all strong proof of their great antiquity, compared with those of a much lower level, in which, to this day, stone pipes and copper articles are found. Further investigation may change this view, but facts at present would seem to point to a time, previous to the breaking away of the great northern barrier, when the sea was on a level with some of the terraces of Lake Ontario.

These vestiges of a proud and once powerful race are traceable from the rude earthen embankments of the North to the extended ruins of Central America, and are worthy of patient and continued investigation, though their unwritten history may never be fully revealed.

It is by the careful collection and preservation of facts, minute though they may be in detail, that a sufficiency of data will be gathered from which some future historian may do justice to the memory of the earlier inhabitants of this continent, and erect a beautifully proportioned and massive ethnological structure.

CORRESPONDENCE.

PHONOGRAPHY.

To the Secretary of the Smithsonian Institution:

The system of writing called phonography has acquired some interest for the public from its singular success as applied to verbatim reporting, for which purpose it is rapidly supplanting all former methods of short hand. But independent of its merits in this regard, it has claims of a scientific character from its philosophic basis, its simplicity, and its adaptedness to a general system of education, which have been less appreciated.

With a view of calling attention to these points, this communication has been prepared in the belief that, if it shall lead any to investigate the system, they will find it not the least among the means of promoting "*the increase and diffusion of knowledge among men.*"

The inventor of phonography, Isaac Pitman, of Bath, England, has sought to combine the perfect phonetic representation of the English language with a selection of signs so simple as to furnish, likewise, a system of short hand. For the phonetic representation of a language, we require, first, an analysis of the sounds heard in speaking it, so as to determine the elements of which it is composed; and, secondly, the selection of a special sign for each distinct sound as thus derived. This done, all that is needful for the representation of any word in writing is to set down the signs agreed on for the sounds in the order in which such sounds appear in the given word; and conversely reading is but the rapid utterance of the sounds indicated by the signs or letters with which the given word is written.

The original from which European alphabets are derived was doubtless phonetic; that is, it had a letter for each sound to be represented, and such sound was uniformly represented by that letter; but at present the traces of such an origin are more or less obscured.

In English this is especially the case, insomuch that we have many elementary sounds in our speech which we have no means of certainly representing; and, on the other hand, letters professedly selected to denote certain sounds are employed for other sounds as well. As a consequence, instead of the harmony and simplicity of a phonetic system, we have one which is essentially arbitrary. Our spelling is determined, not on any fixed principles, but by the force of authority and custom; so that if a word be presented to us for the first time, we cannot feel assured of its spelling from the pronunciation, or of its pronunciation from its spelling, without first referring to the dictionary. Hence the very foundation of modern knowledge, the art of reading and spelling, is beset with peculiar difficulties; and that which, through a phonetic alphabet, is acquired without annoyance in a few months, demands, through the imperfection of our present alphabet, the labor of as many years. An analysis of the English tongue shows that, for its complete phonetic representation, an alphabet of thirty-four elementary sounds is demanded. These sounds are those indicated by the italicized portion of the following words, viz:

*p*it, *t*o, *c*ot, *f*at, *th*eme, *s*eal, ru*sh*.
*b*it, *d*o, *g*ot, *v*at, *th*em, *z*eal, rou*g*e.

*m*ap, *n*ap, ri*ng*, *r*ay, *l*ay, *h*e, *w*e, *y*e.
*ee*l, *ai*l, *a*re, *aw*ed, *o*pe, f*oo*l.
*i*ll, *e*ll, *a*t, *o*dd, *u*p, f*oo*t.

The received alphabet has but twenty effective letters, (since x, q, j, c, i, and u are duplicates, or compounds of simpler elements,) so that fourteen additional letters are required to fit it for the phonetic representation of our language. It is from this deficiency that a consistent system of spelling is rendered impracticable, and that a resort must be had to arbitrary and confusing expedients.

Were the settling of our alphabet and orthography now for the first time proposed as an original question, a phonetic system would of course be adopted; and there are not wanting those who believe that the advantages it would secure in averting the difficulties attendant on acquiring the art of reading, would justify, even now, a reform in that direction. But the inconvenience of a transition from an established to a new system will probably be held to countervail such advantages.

These inconveniences, however, are not encountered in the adoption of a phonetic alphabet for short hand purposes.

In such a case, no acquired knowledge is to be unlearned; no printed books are to be discarded; and the inventor may apply himself to the development of a perfect system, untrammelled by antecedent restraints. Such being the case, it is somewhat surprising, considering the unquestionable advantages of phonetic representation, that Isaac Pitman's system of short hand is the first which has been erected on that basis; and its success affords another illustration of the importance of founding an art on scientific principles, in place of arbitrary rules. For it is in consequence of certain analogies, only clearly brought to notice in his investigation of the phonetic elements of our language, that Isaac Pitman was enabled to secure, what is essential to the success of phonography as a system of short hand—a selection of a simple sign for each simple sound.

It is, of course, impracticable, with the ordinary resources of the printing office, to give here the forms of the letters employed in phonography. It may suffice, in general terms, to explain, that the simplest mathematical signs—the right line, the curve or the segment of a circle, the dot and the dash—furnish the material of the phonographic alphabet. Each sound is expressed by a simple and easy motion of the hand. It follows that the system thus developed meets every requirement for the most rapid writing. It is, in fact, the most perfect method of reporting which has ever been invented, and its phonetic basis renders it also as easy to be read as to be written; so that, in fact, it lacks no requisite for a thoroughly philosophical system of writing; easy to learn, easy to read, capable of reporting the most rapid speech, and indicating the nicest shades of pronunciation.

It may be observed, further, that our language, being derived from a variety of sources, embraces an unusual variety of elementary sounds; comprising nearly all those requisite for the representation of the languages of Europe. By the enlargement of the phonographic alphabet with the few additions requisite for foreign languages, we are able to employ it not merely for English, but for other tongues as well; recording by it with unerring certainty the infinite diversities of peech and pronunciation in use among civilized nations.

A system whose scientific basis is such as has been indicated, and capable of being written with the rapidity previously without a parallel, approves itself to the judgment without argument, as deserving a place in any *well* ordered plan of education. As a means of developing distinctness and accuracy of pronunciation, and a clear knowledge of its nice shades and varieties, nothing can be more useful than the study and practice of phonographic writing and reading; since from the very necessity of writing the sound of the words, our attention is constantly directed towards differences of pronunciation and the ascertainment of that which is correct. Indirectly, therefore, and more thoroughly, it teaches all which is included in the study of orthœpy; and if it were only useful in this particular, it would be well worthy of attention. But when we consider, further, its advantages as a system of short hand, there appear few studies, if we except the very elements of learning, more likely to prove useful, both in the process of acquisition and in the attainment.

The system of long hand writing is far from answering all the requirements of our present state of social and mental advancement. It is not a fancied, but a real want, which phonography meets, when it furnishes a method which makes the representation of words by written characters as facile and easy as is their expression in speech; which combines, in short, the legibility and distinctness of long hand with the brevity and facility of short hand.

Such a system enables students at schools and colleges to secure a verbatim record of the valuable information presented in their course of instruction, and which the unassisted memory is wholly unable to retain. The importance of such information for present use, and as a treasury for future reference, cannot well be over estimated. Nor does the utility of a knowledge of phonography by any means cease when, after completing the studies of youth, we enter on the business of life. The lawyer, the physician, the clergyman, the author, the scholar, and the merchant, versed in the art, will find abundant opportunities to apply it to practical advantage, as a labor-saving instrument in substitution for the cumbrous long hand.

We have already an abundant store of facts proving the practical value of phonography. Apart from its use for reporters' purposes, it is employed among many thousands of persons in this country and Great Britain in interchanging correspondence; by preachers in preparing for the pulpit; and by authors in writing for the press; in which case the printers are taught to set up from phonographic manuscript. Several periodicals are published in lithographed phonography, and find patrons who read them with the facility of ordinary manuscript. But the most striking examples of the value of the system are found among those who adopt it for the purpose of professional reporting. Lads, many years short of manhood, who have had the advantage of acquiring this art, find it the means, not merely of support, but of lucrative remuneration, by becoming amanuenses, or reporters of judicial or legislative proceedings, some of them having been selected for the responsible position of reporters for the Congress of the United States.

The usefulness of the system would be more apparent, were it fairly introduced into our schools as part of an elementary system of educa-

tion, for which purpose, by its simplicity and attractiveness, it is eminently fitted. But, thus far, the knowledge of the art has been spread mainly through self-instruction, and under many disadvantages. It is gratifying to know, however, that phonography, having passed through the ordeal of experiment, is rapidly becoming acknowledged as a necessary branch of education, and is now introduced and taught in a large number of our leading colleges and seminaries, a list of which is appended to this communication.

On behalf of the Philadelphia Phonographic Society.

TOWNSEND SHARPLESS.
ROBERT PATTERSON.

PHILADELPHIA, *January* 10, 1857.

Institutions in which phonography is taught.

Antioch College, Yellow Springs, Ohio.
Oberlin College, Oberlin, Ohio.
Yale College, New Haven, Connecticut.
Green Mount College, Richmond, Indiana.
New York Central College, McGrawville, New York.
Lafayette College, Easton, Pennsylvania.
Williams College, Williamstown, Massachusetts.
Victoria College, Cobourg, Canada West.
College, New Wilmington, Pennsylvania.
American Female College, Glendale, Ohio.
Eleutherian College, Neal's Creek, Indiana.
College, Athens, Ohio.
College, Evanston, Illinois.
Fort Edward Institute, Fort Edward, New York.
Public School, Waltham, Massachusetts.
High School, Providence, Rhode Island.
Madison University, Hamilton, New York.
Union School, Bellefontaine, Ohio.
Delaware Literary Institute, Franklin, New York.
Biblical Institute, Concord, Hew Hampshire.
Theological Seminary, Fairfax county, Virginia.
Conference Seminary, Charlotteville, New York.
Wyoming Seminary, Kington, Pennsylvania.
Goodrich's Seminary, New Haven, Connecticut.
Bedford Harmonial Seminary, Calhoun county, Michigan.
Holly Springs Seminary, Marshall county, Mississippi.
Western Reserve Seminary, Farmington, Ohio.
McNeely Normal School, Hopedale, Ohio.
Southwestern Normal School, Lebanon, Ohio.
University of Michigan, Michigan.
Union School, Granville, Ohio.
Normal School, Oskaloosa, Iowa.
Friends' Boarding School, Richmond, Indiana.
Male Institute, Arkadelphia, Arkansas.
Hopedale Seminary, Milford, Massachusetts.
High School, Philadelphia, Pennsylvania.

CORRESPONDENCE.

PORT OF SPAIN, TRINIDAD, *April*, 1857.

MY DEAR SIR: In my last letter I gave you some idea of the geological structure of this singular island; and also the meteorological fact that hurricanes are never known here, although they have occurred at Tobago, 30 miles east of us. By the accompanying registers you will be enabled to see the minute variations of our mountain barometer, made by Messrs. Troughton & Simms, London. Our aneroids have done good service, particularly that invented by Bourdon & Richards. Our boiling water experiments have not been so satisfactory; I am induced to attribute this to the great humidity of our atmosphere.

I enclose you also a copy of our report, as it may interest you. Our future operations will be over a more interesting country. This report you must not regard as a scientific document, but one written to meet the capacities of the inhabitants of this island. As our future labors are published, if you take any interest in them, I shall have much pleasure in sending them to you. They will embrace our survey of that interesting object, the "Pitch Lake." The difficulty of transit over the low lands during the rainy seasons prevents our carrying on the survey with that system of regularity so desirable. Moreover, we have to limit our researches to very superficial examinations, as they are intended for mineralogical rather than for geological purposes. Various local causes operate against us, particularly the density of the vegetation, which surpasses that of every other country I have visited except the portion of New Granada near the Isthmus of Panama.

I remain, my dear sir, yours, very sincerely,

JAMES G. SAWKINS.

Professor JOSEPH HENRY.

REPORT OF PROGRESS, FROM AUGUST 25, 1856, TO FEBRUARY 24, 1857, OF THE SURVEY OF THE ECONOMIC GEOLOGY OF TRINIDAD.

BY G. P. WALL AND JAS. SAWKINS.

An examination of the Economic Geology of a country necessarily includes several kinds of observations and investigations, viz:

Those appertaining to a Geological Survey proper, in which the nature of the different rocks and strata are ascertained, their mutual relations to one another defined, and the various disturbing causes

which may have affected the district under consideration are determined, with an amount of accuracy which it is permissible to give the investigation.

Should an inspection establish the existence of sedimentary strata, these would probably contain fossils, in which case an examination of these organic remains would be of high importance, whether with the view of discovering the relative geological age of the formation, or for the purpose of comparing them with fossiliferous strata already classified in countries which have been thoroughly surveyed. To render these researches complete, it is also important to institute purely physical investigations, such as the determination of the height relative to the sea level, of characteristic elevations, or depressions, either by barometrical measurements or geodesical operations.

The economic value of the rocks, or minerals contained in the given district, should such be ascertained. Their existence would probably be revealed during the execution of the *geological* survey, and it would be requisite, either during the progress of that work, or after its completion, before concluding as to their value, to determine as far as possible the nature and extent of such deposits of the useful metals; the feasibility of extracting them, of preparing them for commerce, or the industrial processes to which it may be necessary to subject them, before they became available for the use in the arts or manufactures.

In connexion with this department, a series of assays and chemical analyses are highly useful to define the per centage of available product contained in metallic ores, or the relative purity of gypsum, marbles, and other non-metallic substances.

The prospects of obtaining a supply of water by means of Artesian wells are dependent on geological conditions; and as works of this nature prosecuted under favorable geological indications have so often been attended with success, a review of the circumstances which render probable the existence of subterraneous accumulations of water under hydrostatic pressure should not be omitted from any comprehensive survey of the mineral resources of a country.

Another subject which deserves attention is the influence of geological structure on agriculture, as exercised through the medium of the soils, which are derived either from the decomposition of the subjacent strata, or from detrital matter transported by aqueous agency from more elevated land at a distance. Experience proves that after a certain time the richest lands become exhausted by cultivation, and only reacquire their fertilizing properties after a lengthened period of repose; during which the mineral constituents present in the soil are decomposed; thus rendering accessible to vegetative processes those mineral ingredients so essential to the life of plants. An examination, then, of a district under cultivation in connexion with its geological structure may frequently afford data for conclusions as to the relative duration of its fertility, and if exhausted, of the time necessary for its restoration to the productive condition.

The application of chemical analysis to the determination of the elementary constituents of soil may also be included under the head of economic geology. Its utility is manifest, since the comparison of the composition of virgin soil with those cultivated, and of others exhausted, will readily show what elements are extracted by certain plants, and consequently what substances should be contained in the manures applied by the cultivator to regenerate his estates.

Such are the principles which the surveyors appointed to report on the economic geology of Trinidad have kept steadily before them in the execution of their task. In those respects in which they have failed to accomplish the ends indicated above, they trust such defects will be ascribed not to a deficiency of zeal on their part, but rather to the limited means at their disposal; to the difficulties opposed to works of this nature in tropical countries, where many facts of vital importance to correct conclusions are unfortunately concealed, or obscured by the depth of the soil, and where the examination of localities remote from lines of regular traffic is attended with a considerable expenditure of time.

The district examined is comprised between the islands at the Bocas on the west, and the hills above St. Joseph and Ancona Valley on the east. In meridianal extension it ranges from the plain of Caroni to the northern coast. Passing visits were also made to Cedros, Point-à-Pierre, and the Pitch Lake, for the satisfaction of the late governor, Sir Charles Elliot; but the observations were not sufficiently detailed to justify description. The following remarks will therefore relate to the first named section of the country only.

The geological structure of this district consists of a metamorphized strata, probably underlaid by gneiss, which nowhere comes to the surface in Trinidad, but is the rock forming the point of Paria on the adjacent coast of the main land.

This metamorphic series may be divided into the following members:

A. Dark blue, sometimes nearly black limestone, laminar, or compact, not generally crystalline or micaceous, but traversed by numerous veins of calc spar, (carbonate of lime;) it occurs in layers interstratified with shale containing laminar gypsum, and sometimes thin beds of sandstone. This limestone deposit forms the island of Pato, near the coast of the main land, the island of Gasparillo within the gulf, and the southwest portion of the Laventille hills. This is the uppermost number of the series, and has an average dip to the south at a variable angle. The beds are sometimes horizontal, at others nearly vertical. Numerous faults traverse these districts, and the limestones are at times much shattered. This division, as well as the succeeding, are entirely unfossiliferous.

B. A series of beds, consisting of clay slates, sandstones, subordinate mica slates, and a number of shales, often talcose; but little limestone appears in the group; when present its texture is crystalline. Extensive segregations of quartz have been induced between the laminæ of the beds of this system, often attaining a width of two to three feet; contortions are frequent, cleavage imperfect and irregu-

lar, pyrites very abundant. Since clay slates occur in considerable quantity in this system, they may be considered typical of the series.

C consists of crystalline and micaceous limestones not generally traversed by veins of calc spar, in color varying from white to blue, containing numerous caves often partially filled with stalagmitic deposits of crystalline carbonate of lime.

D is composed of mica, chlorite, and quartzose slates; ferruginous shales, especially in the upper portion, whilst the lower is often characterized by dark, apparently carbonaceous slates; the original structure very generally obliterated, but foliation exists in a high degree. The mica usually distinguished by a green color, contortions frequent, and quartz veins of still larger dimensions than in section B, attaining a width of from four to six feet. The average dip of this system is from S. 10° W. to S. 10° E.

The valleys intersecting this district contain alluvial deposits, formed from the degradation of the adjacent hills, and consisting of, 1st, large rounded boulders of quartz and tabular pieces of the various rocks just described.

2d. Beds of smaller boulders and pebbles.

3d. Soil and vegetable mould; between them beds of variegated clay often occur, and indeed the boulders, &c., are usually deposited in the matrix of the same nature.

MINERAL SUBSTANCES ENCOUNTERED IN THE ABOVE FORMATIONS WHICH MAY POSSESS ECONOMIC VALUES.

The compact limestone of section A forms an excellent material for macadamizing, and is further applicable for the purposes of quick-lime, and for building where roughness of finish is not objectionable, but the production of smooth surfaces, such as characterize firestone, would require too great an expenditure of labor.

It has been proposed to apply the white limestone (section C) for building, or inferior marbles; they would, however, probably be available only for ornamental purposes, as these crystalline limestones require very careful cutting to produce surfaces adapted for construction; mica contained in these limestones might often communicate a fissile structure, inducing the too facile separation of a block into several pieces. To test their real value it would be judicious to make experiments on the same scale of magnitude as the articles proposed to be manufactured. The portions free from mica are tolerably pure, containing 96 to 97 per cent. of carbonate of lime. (See analysis furnished to the Colonial Secretary.)

QUARTZ.

The scattered boulders of this substance, found on the hill-sides or in the beds of rivers, might be employed with advantage for the repair of roads when the limestones are not present. Although very hard, it is not sufficiently tough to resist severe friction. In Saxony

a considerable portion of the roads are repaired with this material, and when subject to heavy traffic become very uneven, from unequal resistance. On adjacent portions of the lines of communication, where basalt, a rock both hard and tough, is used, a very even surface is preserved.

GYPSUM

Occurs in beds of shale between the limestone, in a tubular form, but only in small quantities. It exists in abundance near St. Joseph, forming a bed at least twenty feet thick, lying unconformably on highly inclined shales and calcareous slates. This deposit is very pure, containing 93 per cent. sulphate of lime, (analysis furnished to the Colonial Secretary,) and would probably more than suffice in quantity for the wants of the colony.

ALUM

Is found efflorescing on cliffs of mica slate on the north of the Boca Islands; and near Macaripe, on the north coast of Trinidad. An abundant supply of this article might be obtained, but the low price it commands in commerce, and the limited demand for it in this colony, would scarcely justify the outlay of capital for its manufacture.

SULPHUR,

In small quantities, is associated with alum and gypsum deposits, but does not require more than a mere notice of the fact.

SLATES.

The essential properties of good slates are a fine texture, compactness, cohesion in one direction, resisting flexure, and at right angles to this direction a highly fissile structure, depending more or less on cleavage, and which should preserve a straight course in one and the same place. For the advantageous working of a bed of slate it must have a moderate width, and be tolerable free from quartz veins, and other extraneous matter, which might destroy the regularity of the structure. Although small pieces fulfilling all the requisites may be obtained from the quarry at St. Ann's, generally the coarseness of texture, the absence of transverse cohesion, the irregularity of cleavage, and the interference of quartz veins, will prevent the application of these slates to roofing purposes, but they may possess some slight value in cases where the qualities just described can be partially or wholly dispensed with.

GOLD.

Reports have been circulated of the discovery of gold in the oxides of iron, associated with quartz veins traversing clay slates at St. Ann's quarry; to ascertain the accuracy of such reports, four specimens of

ferruginous quartz and three of gravel from the stream flowing at the base of the section exposed were submitted to the gold assay without, however, detecting the slightest trace of that metal.

Another specimen in Mr. Cruger's possession, given to him as auriferous, and as proceeding from the slate quarry, was a dark green slate, with disseminated pyrites, but quite dissimilar to any of the strata detected in the section at the quarry. On examination it yielded the remarkably insignificant amount of .00009 per cent. of silver, or .03 ounce per ton, containing also a minute quantity of gold. It may be remarked that traces of gold are often present in pyrites, but not to such an extent as to warrant extraction, for which, in the case referred to, about 250 tons, the amount indicated, would be requisite.

QUARTZ VEINS AND MINERAL LODES.

In reference to quartz veins it may be well to explain that they must be distinguished from mineral veins, or lodes, which are mechanical fissures, first open, and afterwards filled with metallic ores and a variety of other minerals. No indication of the existence of such fissures has been detected during the geological survey. The former are due to metamorphic action, which has induced the segregation of the excess of quartz into the lines of weakness between the laminæ of the strata produced by the stratification or cleavage; the instances of metals or metallic ores associated with these veins are exceptional, although the substance next to be considered affords an illustration of its occurrence, viz:

IRON.

The oxide of this metal is intimately mixed with quartz in certain strata of this district, belonging to the mica slate or lowest division, and found especially abundant in the "Quebrada de Hierro." Magnetic and specular iron ores, free from quartz and containing 60 to 66 per cent. of metallic iron are found traversing quartzose slates, and sandstones parallel to the laminar structure, and filling joints, or any minor crevices which may exist. These iron ores are present in considerable quantities, and the metal might undoubtedly be produced from them, as the abundance of wood in the vicinity furnishes the charcoal necessary for smelting; it is also probable the iron would be of good quality, but the experience of other countries shows that the segregated ores of iron contained in the metamorphic rocks are both expensive in extracting and difficult of reduction to the metallic state.

Considering these facts in connexion with the high price of skilled labor, and the low price at which imported iron is furnished, it is doubtful whether the attempt to work these deposits would be attended with profit. The ores of iron are found so abundantly in the countries, which are the seats of its manufacture, that the expenses of extraction and transport would scarcely allow the colonial ores, however rich, to be advantageously exported. The blocks of iron ore found at Gasparilla, though rich, are apparently present to a limited extent only.

CHROMIC IRON ORE.

This valuable mineral was said to have been met with in Laventille. The specimen obtained bears a striking resemblance to titanic iron, and on analysis was proved to contain only 1.02 per cent. chromic acid; while to be available as a commercial article, it should contain from 40 to 45 per cent. of this substance, which gives importance to the mineral.

SILVER LEAD ORE.

This mineral, so often reported to exist in the district of Santa Cruz, and of which samples have been frequently exhibited, was the subject of a careful search in the localities indicated, but nothing differing from the features of the adjacent country could be detected, no signs of mineral deposits, no trace of metallic combinations, or the usually associated minerals; the specimens produced were those of an ordinary lead ore, and contained 81 per cent. of lead, and 3.33 ounces of silver to the ton, which small amount would not repay extraction.

QUICKSILVER.

It has also been currently reported and believed that there exists a deposit of mercury in strata adjacent the Dry river; without any desire to discredit the fact of the mercury having been found there, it may be stated that a particular examination of the locality appears to indicate that its presence was the result of accident, and not due to any natural deposit of that metal.

MINERAL SPRINGS.

The only one in this district likely ever to be of importance is the tepid sulphur spring, which rises in the bed of the St. Joseph's river, not far from the valley leading to the Cascade; it is similar to those mineral waters which have proved so highly beneficial in cutaneous diseases. The White Sulphur Spring, in Virginia, is annually resorted to by many thousands of visitors, who, whilst adding to the wealth of the vicinity, derive great benefit from the use of the waters.

PITCH DEPOSITS WHICH MAY PROVE AVAILABLE FOR GAS.

These remarks on the mineral value of the portion of the island explored should not be concluded without allusion to the abundant supply of pitch existing in the marls and clays of the western section of the country, since so many applications of this are proposed and the question of the success of some is now in course of solution.

The substance itself, and more particularly the adjacent strata impregnated with pitchy matters, bear a resemblance in mineral character to the bituminous shales of Scotland, now attracting so much attention in the home country, on account of the large proportion of gas extracted from them, for which reason they command a price far

exceeding that of ordinary coals. The latter are merely earthy beds impregnated with bitumen, not applicable as fuel, from the circumstance that the combustible portion melts, and flows through the bars of the furnace, but generating an amount of gas ,in some instances, double the volume of that obtained from the regular coals. The Trinidad pitch formation also consists of bituminous elements intimately mixed with a variable per centage of earthy matter. It is natural to conclude that well directed experiments might produce results appoximating to those afforded in the instances referred to.

ATMOSPHERIC INFLUENCES.

Atmospheric variations in all climates have a material influence on the harvests of a country, and nothing less will suffice to the full understanding of the peculiarities of climate than the comparison of observations on atmospheric phenomena made throughout entire years. On this account, a record of meteorological data has been executed by the geological department, and on a scale as complete as circumstances would allow.

ANALYSIS OF SOILS.

The elementary constitutions of the soils, as well as their exhaustion by cultivation, has also received attention, and a series of chemical analysis of typical soils, and subsoils, is in progress, but the great expenditure of time involved in researches of this nature has rendered it difficult to combine them with the duties more especially appertaining to the department.

PICTORIAL REPRESENTATIONS.

No written descriptions of a country can convey so faithful an idea of its structure or appearance as when accompanied by pictorial representations. The district geologically examined is amply illustrated by drawings of interesting scenery and peculiar geological features.

SPECIMENS.

The specimens collected during the examination, and illustrative of the geology of the island, are arranged at the office of the survey, for the inspection of such as experience an interest in the progress of the inquiry.

ON TABLES OF THE CONSTANTS OF NATURE AND ART.

BY CHARLES BABBAGE.

Amongst those works of science which are too large and too laborious for individual efforts, and are therefore fit objects to be undertaken by united institutions, I wish to point out one which seems eminently necessary at the present time, and which would be of the greatest advantage to all classes of the scientific world.

I would propose that its title should be "*The Constants of Nature and of Art.*" It ought to contain all those facts which can be expressed by numbers in the various sciences and arts. A better idea will be formed by giving an outline of its proposed contents, and it may, perhaps, be useful to indicate the sources whence much of the information may be drawn.

These constants should consist of—

1. All the constant quantities belonging to our system: as distance of each planet; period of revolution; inclination of orbit, etc.; proportion of light received from sun; force of gravity on surface of each.

These need not be further enumerated, as they have already been collected, and need only be copied.*

2. The atomic weights of bodies.

These may be taken from Berzelius, Thompson, or Turner.

The proportions of the elements of various compounds; acids with bases; metals with oxygen, etc.

These may be taken from the best treatises on chemistry.

3. A list of metals, with columns containing specific gravity, elasticity, tenacity, specific heat, conducting power of heat, conducting power of electricity, melting point, refractive power, proportion of rays reflected out of 1,000, at an incidence of 90°.

List of specific gravities of all bodies.

4. List of refractive indices.
dispersive indices.
polarizing angles.

4. List of angle formed by the axes of double refraction in crystals.

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* A work of this kind, embodying the results of sicence, has been projected for sometime by M. Poggendorff, of Berlin, and a specimen of it may be seen in his *Annalen*, xxi, p. 609

These may be extracted from the writings of Brewster, Mitscherlich, Herschel, Biot.

5. Number of known species of mammalia, birds, reptiles, fishes, mollusca, worms, crustacea, insects, zoophytes.

These classes might be further subdivided.

Additional columns should show how many of each are found in a fossil state, and the proportion between the fossils of existing and extinct species.

6. List of mammalia, containing columns expressing height, length, weight, weight of skeleton, weight of each bone, its greatest length, its smallest circumference, its specific gravity; also the number of young at a birth, the number of pulsations per minute whilst the animal is in repose, the number of inspirations in the same circumstances, period of blindness after birth, period of sucking, period of maturity, temperature, average duration of life, proportion of males to females produced.

It would be desirable to select some bone for the unity of weight, and perhaps of measure, and to give the proportion of all the other bones to this standard one. The numerical relations thus established might perhaps in some cases identify the sexes, or even the races of the human species, when only a few bones were found. It would also be highly interesting to compare the relative weight of the bones of persons employed in different trades, and of persons dying from certain constitutional diseases.

7. Of man. Average weight at various periods of existence, height of ditto, tables of mortality in various places, average duration of reigns of sovereigns; proportions of the sexes born under various circumstances; proportion of marriages under various circumstances; quantity of air consumed per hour; quantity of food necessary for daily support; average proportion of sickness amongst working classes; proportion of persons dying from different diseases.

Many of these facts may be found in the writings of Villermé, Quetelet, Bailly, Milne, etc.

8. Power of man and animals.

A man laboring ten per hours per day will saw ( ) square feet of deal, ditto ( ) elm, ditto ( ) oak, etc., ditto Portland stone, ditto Purbeck; days labor in mowing, ploughing, etc., etc., every kind of labor, raising water one foot high, horse ditto, ox or cow ditto, camel.

Power of steamengines in Cornwall.

Inclination of a road, both in degrees and number of feet, etc., or of a base on which carriages and horses can trot, walk; on which horses cannot ascend, on which man cannot, on which a cart cannot ascend.

9. Vegetable kingdom. Number of species known of monocotyledonous plants; number of species of dicotyledonous plants.

Number of species of the various natural groups.

Additional columns should show the number of species known in a fossil state, together with that of extinct fossil species.

Also, average weight of vegetable produce of one acre in a year,

when under different modes of cultivation; hay, straw, wheat, turnips, and mangel wurzel, potatoes, clover; etc. produce of timber per acre.

10. Tables of the geographical distribution of animals and of plants; of the average period of maturity and decay in various woods; increase in weight annually at different periods; weight of potass produced from earth; proportion of heat produced by burning given weight.

11. Atmospheric phenomena. Weight of air above a square inch; square foot; an acre; a square mile of the earth's surface, barometer at 30 inches. Weight of oxygen, of nitrogen, of carbonic acid, above the same spaces, under the same circumstances.

Weight of water in vapor above ditto at various degrees of hygrometer. Depth of rain falling annually at various places, in inches, columns for number of year's observation, mean temperature, mean height of barometer, height of places above the sea; drainage of surface-water for one, two, three, to ten inches, from each square of 100 feet side, each acre, or square mile, expressed in cubic feet, in gallons, and in hogsheads; water discharged per″ or 1′, per hour or per day, under various circumstances, as found by experiment; velocity of rivers and torrents to carry stones of given weight.

12. Materials. Height to which a column of any substance used in building may be carried before the lowest layer is crushed; weight necessary to crush a cubic inch of each; weight of cubic foot or cubic yard. Angles at which sand, gravel of various sized pebbles, snow, etc., support themselves. Strength necessary to pull asunder various woods; bars of metal of various dimensions; weight to break ropes and chains of various sizes; column for weight to be safely borne by them; friction under various circumstances; resistance of fluids.

Weight of coal to burn 10 bushels of lime; weight of ashes to burn 10,000 brick; of coke to make ton of wrought-iron; tallow to make soap, etc.; and constants in all trades.

See Rennie, Tredgold, Prony, Eytelwein, Venturi, etc.

13. Velocities. Arrow, musket ball at several distances, cannon ball, sound, telegraph, light, birds.

Day's journey. Man, horse, heavy wagon, stage-coach, mail-coach, camel, elephant, steam carriage, steamboat, balloon, greatest; average passage Liverpool to New York, etc., of steamboats, Dublin to Liverpool; London to Edinburgh, etc.

14. Length of all rivers; water discharged per hour; seas; proportion of water to land on globe; area of all seas and lakes in square miles; areas of all islands and peninsula and continents; heights of mountains; depth of mines from surface; quantity of water pumped out of mines.

Heights of above 7,000 points in Europe may be found in *Orographie*, the third volume of the *Transactions of the Geographical Society of Paris.*

15. Population, extent in square miles, revenue, etc., of kingdoms; births, deaths, marriages, rate of increase, population of great towns.

16. Buildings. Height of all temples, pyramids, churches, towers, columns, etc.; also all single stones, as obelisks, and area covered by ditto; area of all great public buildings. Dimensions of all columns in ancient temples; lengths of all bridges; of span of each arch, and height, also breadth of piers.

Such tables may be found in Wiebeking, *Architecture Civile*, in—.

17. Weights, measures, etc., factors and their logarithms to convert all money of every country into English pounds sterling.

Factors and their logarithms to convert weights of every country into English pounds avoirdupois.

foot and all measures in every country into English feet.

measures of area, acres, etc., into English acres.

liquid measures in every country into English imperial gallons.

These are already collected in several works of Löhmann, of Dresden. See also *Universal Cambist.*

18. Tables of the frequency of occurrence of the various letters of the alphabet in different languages; of the frequency of occurrence of the same letters at the beginnings or endings of words; as the second or as the penultimate letters of words; of the number of double letters occurring in different languages; of the proportion of letters commencing surnames amongst different nations.

See Quetelet, *Correspondence math.*, also *Dissertatio inauguralis mathematica de literarum proportionibus*, Éd. Hayez, Bruxelles, 1829.

19. Table of number of books in great public libraries at given dates; number of students at various universities. Observatories of the world; transit, its length, diameter of object-glass, maker; circle, length of telescope, aperture, diameter of divided circle, maker.

It would be desirable to give the date of the different eras by which time is computed, and perhaps tables of the reigns of sovereigns. Also a chronological table, at least of scientific discoveries and their authors.

In the above enumeration, which is far from complete, some few of the uses of such a volume are noticed; others will present themselves to every reader, and probably many unexpected ones will arise. The facts being all expressed in numbers, if printed in small type and well arranged, would not occupy a large space. Most of the constants mentioned in this list already exist, and the difficulty of collecting them would consist chiefly in a judicious selection of those which deserve the greatest confidence. The labor of extracting them from a great variety of volumes, and of reducing the weights and measures of other countries to our own, could be performed by clerks. To any individual who might attempt it, it must be a work of great labor and difficulty, and there are few persons possessing the varied knowlege which such a task implies, whose talents might not be differently employed with more advantage to science. It is also certain that such an assemblage of facts, emanating from the collected judgment of many, would naturally command greater attention than if it were the produce of any single individual, however eminent.

It appears, then, that such a work is particularly fitted to be the

production of a body of men of science, and I would appeal to the great academies of Europe whether they would not, by combining in one volume so vast a collection of facts, confer an important advantage upon science and upon all who are occupied with its pursuits. I would suggest that three of the academies of Europe, perhaps the Royal Society, the Institute of France, and the Academy of Berlin, should each publish at intervals of six years their own table of the CONSTANTS OF NATURE AND ART. Thus these publications might succeed each other at intervals of two years, and the man of science would always be able to refer to the most recent determinations of the constants he employs.

In order to execute the work, sub-committees of one or two persons must be appointed to each department, who should be directed in the first instance to prepare the outline of the constants they propose to insert. These views should then be considered and classed by a small committee, consisting of persons of general views and various knowledge. The sub-committee should then collect and reduce to certain standards the constants committed to them, and the whole should be printed under the general superintendence of the committee, but each part should be specially revised by its own sub-committee.

A preface should be prepared, stating as briefly as possible the reasons for preferring or rejecting particular experiments or observations and also, generally, the degree of accuracy the several subjects admit of. A good and concise system of reference should be made to all the authorities for the numbers given. Whoever should undertake the first work of this kind would necessarily produce it imperfect, partly from omission, and partly from the many facts connected with natural history, which, although measured by number, have not yet been counted.

But this very deficiency furnishes an important argument in favor of the attempt. It would be desirable to insert the heads of many columns, although not a single number could be placed within them, for they would thus point out many an unreaped field within our reach which requires but the arm of the laborer to gather its produce into the granary of science.

It is, however, to be hoped that no fear of the imperfection of a first attempt will deter either any individual or any body of men from an immediate endeavor to produce a work fraught with so many advantages to knowledge. The task of revising it at each period of six years will be comparatively easy, and the discussions of new observations or additional experiments made during those intervals will have an admirable effect in exciting the ambition of the inquirers to bestow such care as shall claim for their results a place in the volume, in which the academy shall record the condensed expression of the knowledge of their age and nation.

If I should be successful in inducing any scientific institution to enter in the task, I am confident that many a weary hour, now wasted in the search for existing knowledge, will be devoted to the creation of new, and that it will thus call into action a permanent cause of advancement towards truth, continually leading to the more accurate

determination of established facts, and to the discovery and measurement of new ones.

The following list of those facts relating to mammalia, which can be expressed by numbers, was first printed in 1826. It was intended as an example of *one* chapter in a great collection of facts which the author suggested under the title of the "CONSTANTS OF NATURE AND ART." About 200 copies were circulated at that period. The number of persons, however, then engaged in cultivating science was small, and the author's own pursuits prevented him from attempting to fill up any part of the details of the subject. The want of some central body to which individual results might be confided for the purpose of arrangement also impeded the publication of such results as may have been collected.

The present time offers a far more favorable combination of circumstances. Science itself is cultivated by a much larger number of persons. Stationary scientific societies have become more special in their particular objects. Other societies assembling periodically in different cities have brought into personal acquaintance men of all countries following kindred pursuits. The newest feature of the times, "congresses for special objects," bring together men who have deeply studied those objects, who have felt the want of union as an impediment to their advancement, and who assemble together to agree upon principles and methods of observation, which, whilst they shorten the labor of individual research, contribute towards rendering most productive the united efforts of the collective body of inquirers.

The accompanying skeleton of facts susceptible of measure, appertaining to mammalia alone, might occupy usefully a large number of different inquirers. If those distinguished men who are at the head of the great schools of comparative anatomy would suggest to their pupils the measurement and weight of the various skeletons of animals occasionally coming under their control, much advantage would be derived from the exercises afforded to the students, whilst, by causing these successive measurements of the same individual to be made and recorded by several pupils, any casual error would be corrected.

The directors of zoological gardens and other menageries might readily supply a daily account of the food consumed by the animals, whilst every intelligent visitor might himself count and register the inspirations of the animals. Even in the farm-house and in the country village several of these inquiries might be successfully pursued. The proportion of the sexes amongst our poultry and our domesticated animals, the rates of their pulse and their inspirations, are at present unrecorded in works of natural history.

In order to promote and render useful these contributions of individuals, it is essentially necessary that some centre of action should be arranged, to which all communications should be addressed, and by which they should be recorded from time to time in the periodical publications of the day. When a sufficient number had thus accumulated, a special memoir on the subject might be contributed to some philosophical society, in which the deductions arising from these facts might be pointed out, and the most interesting direction of further researches indicated.

It is scarcely to be expected that any one individual will, even for a single animal, be able to fill up the whole of the measures pointed out in this short paper, and it would be much to be regretted if this enumeration should from its extent discourage any observer. As, however, some definite portions of this labor, within reach in the course of the next twelvemonth, might perhaps, if accomplished, supply a stimulus to more extensive inquiries, I would propose to those who possess microscopes the determination of the diameter of the globules of the blood of various animals, and to those who are not in the possession of such instruments, or cannot spare the time necessary for their use, I would propose the determination of the rate of breathing of various mammalia. The numerous collections of animals now distributed over the continent would render this limited portion of the task a work of comparatively little difficulty.

OBSERVATIONS.

Name.

1. Length from tip of tail to end of nose.
2. Height from ground to top of shoulder.
3. Length of tail.
4. Length of head.
5. Greatest breadth of head.
6. Weight of animal.
7. Weight of skeleton.
8. Number of mammæ.
9. Period of gestation, in days.
10. Period of blindness after birth.
11. Period at which they cease sucking.
12. Period of maturity.
13. Period of old age.
14. Number of young at a birth.
15. Proportion of males to females.
16. Animal heat; thermometer centigrade.
17. Number of pulsations per minute, awake, asleep.
18. Number of inspirations per minute, awake, asleep.
19. Number of species known.
20. Number of toes or claws on fore foot.

OBSERVATIONS.

	Name.	
21.	Number of toes or claws on hind foot.	
22.	Divisions of hoof.	
23.	Facial angle.	
24.	Nature of food, average weight in 24 hours.	
25.	Excretions, solid and fluid, in 24 hours.	
26.	Velocity in motion.	
27.	Day's journey.	
28.	Weight carried.	
29.	Greatest length.	Cranium.
30.	Breadth at ears.	Cranium.
31.	Height.	Cranium.
32.	Weight.	Cranium.
33.	Specific gravity.	Cranium.
34.	Breadth between inner corners of eyes.	Cranium.
35.	Length.	Lower jaw.
36.	Greatest breadth.	Lower jaw.
37.	Specific gravity.	Lower jaw.
38.	Length.	Horns.
39.	Distance from tip to tip.	Horns.
40.	Weight of each.	Horns.
41.	Specific gravity.	Horns.
42.	Weight.	Clavicula.
43.	Specific gravity.	Clavicula.
44.	Weight.	Scapula.
45.	Specific gravity.	Scapula.
46.	Greatest length.	Humerus.
47.	Greatest diameter at upper end.	Humerus.
48.	Greatest diameter at lower end.	Humerus.
49.	Smallest diameter.	Humerus.
50.	Weight.	Humerus.
51.	Specific gravity.	Humerus.

OBSERVATIONS.

	Name.	
52.	Length.	Radius
53.	Smallest diameter.	
54.	Weight.	
55.	Specific gravity.	
56.	Length.	Ulna.
57.	Smallest diameter.	
58.	Weight.	
59.	Specific gravity.	
60.	Number.	Carpal bones.
61.	Length of each or of largest.	
62.	Weight of ditto.	
63.	Specific gravity.*	
64.	Number.	Metacarpal bones.
65.	Length of each or of largest.	
66.	Weight of ditto.	
67.	Specific gravity.	
68.	Number.	Finger bones.
69.	Weight of each or largest.	
70.	Spec. grav. of ditto.	
71.	Number.	True ribs.
72.	Spec. grav.	
73.	Number of false ribs.	
74.	Length.	Femur.
75.	Smallest diameter.	
76.	Weight.	
77.	Spec. grav.	
78.	Length.	Tibia.
79.	Smallest diameter.	
80.	Weight.	
81.	Spec. grav.	

* The specific gravity of the bones is to be given, exclusive of the cavities.

OBSERVATIONS.

Name.		
82.	Length.	Fibula.
83.	Smallest diameter.	Fibula.
84.	Weight.	Fibula.
85.	Spec. grav.	Fibula.
86.	Number.	Tarsal bones.
87.	Length of each or of largest.	Tarsal bones.
88.	Weight of ditto.	Tarsal bones.
89.	Spec. grav.	Tarsal bones.
90.	Number.	Metatarsal bones.
91.	Length of each or of largest.	Metatarsal bones.
92.	Weight of ditto.	Metatarsal bones.
93.	Spec. grav. of ditto.	Metatarsal bones.
94.	Length.	Sternum.
95.	Spec. grav.	Sternum.
96.	Total number.	Vertebræ.
97.	Total length.	Vertebræ.
98.	Number of cervical.	Vertebræ.
99.	Total length of ditto.	Vertebræ.
100.	Weight of each.	Vertebræ.
101.	Spec. grav. of each.	Vertebræ.
102.	Number of dorsal.	Vertebræ.
103.	Total length of ditto.	Vertebræ.
104.	Weight of each.	Vertebræ.
105.	Spec. grav. of each.	Vertebræ.
106.	Number of lumbar.	Vertebræ.
107.	Total length of ditto.	Vertebræ.
108.	Weight of each.	Vertebræ.
109.	Spec. grav. of each.	Vertebræ.
110.	Number of sacral.	Vertebræ
111.	Total length of ditto.	Vertebræ
112.	Weight of each.	Vertebræ
113.	Spec. grav. of each.	Vertebræ

OBSERVATIONS.

	Name.		
114.	Number of caudal.	Vertebræ.	
115.	Total length of ditto.		
116.	Weight of each.		
117.	Spec. grav. of each.		
118.	Grinders. Number.	Upper jaw	Teeth.
119.	Weight of each.		
120.	Spec. grav. of each.		
121.	Canine.		
122.	Weight of each.		
123.	Spec. grav. of each.		
124.	Incisive.		
125.	Weight of each.		
126.	Spec. grav. of each.		
127.	Grinders.	Lower jaw	
128.	Weight of each.		
129.	Spec. grav. of each.		
130.	Canine.		
131.	Weight of each.		
132.	Spec. grav. of each.		
133.	Incisive.		
134.	Weight of each.		
135.	Spec. grav. of each.		
136.	Structure of grinders.		
137.	Proportion of weight of cerebrum to that of body.		
138.	Proportion of weight of cerebrum to cerebellum.		
139.	Length of intestinal canal.		
140.	Proportion of intestinal canal to length of body.		
141.	Proportion of intestinal canal to its circumference.		
142.	Diameter of the globules of blood.		

Blank table of measurements for mammals adopted by the Smithsonian Institution.

SPECIES—

General dimensions.	Inches and 100ths.	Inches and lines.	100ths of length.	Inches and 100ths.	Inches and lines.	100ths of length.	Inches and 100ths.	Inches and lines.	100ths of length.
1. Nose to occiput									
2. Nose to eye									
3. Nose to ear									
4. Nose to root of tail									
5. Nose to end of outstretched hind legs									
6. Tail from root to end of vertebrae									
7. Tail from root to end of hairs									
8. Ears: height, posteriorly									
9. Ears: height, anteriorly									
10. Ears: height, internally above skull									
11. Ears: width									
12. Arm: between claws across shoulder									
13. Arm: length of fore arm									
14. Arm: from elbow to end of claws									
15. Arm: fore foot to end of claws									
16. Arm: longest claw									
17. Leg: from knee joint to end of claws									
18. Leg: tibia									
19. Leg: hind foot from heel to end of claws.									
20. Leg: longest claw									
21. Weight									

NOTE.—The measurements of most importance are Nos. 1, 4, 6, and 7, and should, whenever possible, be made before skinning, as they can never be obtained with accuracy from the prepared specimen.

Blank table of measurements for the skulls of mammals.

Skull.	Inches and 100ths.	Lines.	100ths of length.	Inches and 100ths.	Lines.	100ths of length.	Inches and 100ths.	Lines.	100ths of length.
1. Total length									
2. Greatest width									
3. Distance between orbits									
4. Nasal bones, length									
5. Nasal bones, width behind									
6. Nasal bones, width before									
7. Upper incisors from front to molars									
8. Upper incisors from front to hinder margin of palate									
9. Upper incisors, height									
10. Upper incisors, width between external edges									
11. Upper molars, length taken together									
12. Upper molars, distance between									
13. Lower jaw, length									
14. Lower jaw, height									

Blank table of measurements for fishes.

SPECIES—

Rays.	P.	V.	D.	A.	C.

BODY.

General shape

Greatest height

Greatest thickness

Greatest height to length, as ::

Greatest thickness to greatest height, as ::

HEAD—(side) to length, as ::

HEAD—(above) to length, as ::

MOUTH.

Most projecting jaw, mouth shut

Distance from centre of eye to the snout to same distance to end of operculum, in diameters of eye, as

Distance from snout to tip of operculum, in diameters of eye

Relation of nape to angle between lines from centre of eye to two extremities of commissure

Relations of the eye to anterior edge of operculum

Mucous lines

FINS.

Dorsal—Relation to centre of axis

" " ventral

" " anal

" Base to height ::

" Last ray to longest ::

Total length of 100ths

Pectoral—Relation to dorsal

" " to ventral

Total length in 100ths

Ventral—Relation to anal

Total length in 100ths

Anal—Base to height ::

" Last ray to longest ::

Total length in 100ths

Caudal—Shortest central ray to longest ::

Total length in 100ths

SCALES.

Curve and position of the lateral line

Number of scales in lateral line

Rows from dorsal line in front of dorsal ray to lateral line

Rows from lateral line to base of ventral

Rows encircling body posterior to dorsal fin

Rows around the tail

Oblique rows from nape to dorsal

Oblique rows from dorsal to caudal

Number of vertebræ

The capital letters at the head of the preceding table refer: P. to the pectoral fin; V. to the ventral; D. to the dorsal; A. to the anal; C. to the caudal; and the blanks after each are to be filled up with the number of bony rays in each fin.

The unit of measure is considered to be the total length of the fish divided into 100 equal parts. All the dimensions may be given in terms of this unit. In order to obtain the number of hundredths of the total length of the fish in any given amount, it is only necessary to use the total length in inches and hundredths as a constant denominator. Thus, in a fish 7.35 inches long, a height of 2.55 inches would be $\frac{255}{735}$, or about .35 of the total length.

The most important measurements for birds are: the length from point of bill to end of tail, the distance between the tips of the outstretched wings, and the distance from the first or carpal joint to the end of the longest primary quill. These should always be taken before skinning, and recorded on the label; other important measurements which can be taken from the dried specimen, however, are, the length of the bill along the upper edge and along the cleft of the mouth, the length of the tarsus, and the length of the longest and shortest tail feathers. The colors of the iris, the inside of the mouth, the bill and the feet, may also be recorded to advantage, especially the first mentioned.

[The physical tables now in process of stereotyping, which have been prepared under the direction and at the expense of the Smithsonian Institution by Professor Guyot, will form a part of the important work proposed in this article.]

ON THE MODE OF TESTING BUILDING MATERIALS,

AND AN ACCOUNT OF THE MARBLE USED IN THE EXTENSION OF THE UNITED STATES CAPITOL.

BY PROFESSOR JOSEPH HENRY,

SECRETARY OF THE SMITHSONIAN INSTITUTION.

[Read before the American Association for the advancement of science.]

A commission was appointed by the President of the United States, in November, 1851, to examine the marbles which were offered for the extension of the United States Capitol, which consisted of General Totten, A. J. Downing, the Commisioner of Patents, the Architect, and myself. Another commission was subsequently appointed in the early part of the year 1854 to repeat and extend some of the experiments, the members of which were General Totten, Professor Bache, Captain Meigs, and myself.

A part of the results of the first commission were given in a report to the Secretary of the Interior, and a detailed account of the whole of the investigations of these committees will ultimately be presented in full in a report to Congress, and I propose here merely to state some facts of general interest, which may be of importance to those engaged in similar researches.

Though the art of building has been practised from the earliest times, and constant demands have been made, in every age, for the means of determining the best materials, yet the process of ascertaining the strength and durability of stone appears to have received but little definite scientific attention; and the commission, who had never before made this subject a special object of study, were surprised with unforeseen difficulties at every step of their progress, and came to the conclusion that the processes usually employed for solving these questions are still in a very unsatisfactory state.

It should be recollected that while the exterior materials of a building are to be exposed for centuries, the conclusions desired are to be drawn from results produced in the course of a few weeks.

Besides this, in the present state of science, we do not know all the actions to which the materials are subjected in nature, nor can we fully estimate the amount of those which are known.

The solvent power of water, which even attacks glass, must in time produce an appreciable effect on the most solid material, particularly where it contains, as the water of the atmosphere always does, carbonic acid in solution. The attrition of silicious dusts, when blown against a building, or washed down its sides by rain, is evidently operative in wearing away the surface, though the evanescent portion

removed at each time may not be indicated by the nicest balance. An examination of the basin which formerly received the water from the fountain at the western entrance of the Capitol, now deposited in the Patent Office, will convince any one of the great amount of action produced principally by water charged with carbonic acid. Again, every flash of lightning not only generates nitric acid—which, in solution in the rain, acts on the marble—but also by its inductive effects at a distance produces chemical changes along the moist wall, which are at the present time beyond our means of estimating. Also, the constant variations of temperature from day to day, and even from hour to hour, give rise to molecular motions which must affect the durability of the material of a building. Recent observations on the pendulum have shown that the Bunker Hill monument is scarcely for a moment in a state of rest, but is constantly warping and bending under the influence of the ever varying temperature of its different sides.

Moreover, as soon as the polished surface of a building is made rough from any of the causes aforementioned, the seeds of minute lichens and mosses, which are constantly floating in the atmosphere, make it a place of repose, and from the growth and decay of the microscopic plants which spring from these, discoloration is produced, and disintegration assisted. But perhaps the greatest source of dilapidation in a climate like ours is that of the alternations of freezing and thawing which take place during the winter season; but though the effect of this must be comparatively large, yet, in good marble, it requires the accumulated results of a number of years in order definitely to estimate its amount.

From a due consideration of all the facts, the commission are convinced that the only entirely reliable means of ascertaining the comparative capability of marble to resist the weather is to study the actual effects of the atmosphere upon it, as exhibited in buildings which for years have been exposed to these influences. Unfortunately, however, in this country, but few opportunities for applying this test are to be found. It is true some analogous information may be derived from the examination of the exposed surfaces of marble in their out crops at the quarry; but in this case the length of time they have been exposed, and the changes of actions to which they may have been subjected during, perhaps, long geological periods, are unknown; and since different quarries may not have been exposed to the same action, they do not always afford definite data for reliable comparative estimates of durability, except where different specimens occur in the same quarry.

As we have said before, the art of testing the quality of stone for building purposes is at present in a very imperfect state; the object is to imitate the operations of nature, and at the same time to hasten the effect by increasing the energy of the action, and, after all, the result may be deemed but as approximative, or, to a considerable degree, merely probable.

About twenty years ago an ingenious process was devised by M. Brard, which consists in saturating the stone to be tested with a solution of the sulphate of soda. In drying, this salt crystallizes and expands, thus producing an exfoliation of surface which is supposed to

imitate the effect of frost. Though this process has been much relied on, and generally employed, recent investigations made by Dr. Owen lead us to doubt its perfect analogy with that of the operations of nature. He found that the results produced by the actual exposure to freezing and thawing in the air, during a portion of winter, in the case of the more porous stones, produced very different results from those obtained by the use of the salt. It appears from his experiments that the action of the latter is chemical as well as mechanical.

The commission, in consideration of this, have attempted to produce results on the stone by freezing and thawing by means of artificial cold and heat. This process is, however, laborious; each specimen must be inclosed in a separate box fitted with a cover, and the amount of exfoliation produced is so slight that in good marble the operation requires to be repeated many times before reliable comparative results can be obtained. In prosecuting this part of the inquiries unforeseen difficulties have occurred in ascertaining precisely the amount of the disintegration, and it has been found that the results are liable to be vitiated by circumstances which were not foreseen at the commencement.

It would seem at first sight, and the commission when they undertook the investigation were of the same opinion, that but little difficulty would be found in ascertaining the strength of the various specimens of marbles. In this, however, they were in error. The first difficulty which occurred was to procure the proper instrument for the purpose. On examining the account of that used by Rennie, and described in the Transactions of the Royal Society of London, the commission found that its construction involved too much friction to allow of definite comparative results. Friction itself has to be overcome as well as the resistance to compression, and, since it increases in proportion to the pressure, the stronger stones would appear relatively to withstand too great a compressing force.

The commission first examined an hydraulic press, which had previously been employed in experiments of this kind, for the use of the government, but found that it was liable to the same objection as that of the machine of Rennie. They were, however, extremely fortunate subsequently in obtaining, through the politeness of Commodore Ballard, commandant of the navy yard, the use of an admirable instrument devised by Major Wade, late of the United States army, and constructed under his direction for the purpose of testing the strength of gun metals. This instrument consists of a compound lever, the several fulcra of which are knife edges, opposed to hardened steel surfaces. The commission verified the delicacy and accuracy of the indications of this instrument by actual weighing, and found, in accordance with the description of Major Wade, the equilibrium was produced by *one* pound in opposition to *two hundred*. In the use of this instrument the commission were much indebted to the experience and scientific knowledge of Lieutenant Dahlgreen, of the navy yard, and to the liberality with which all the appliances of that important public establishment were put at their disposal.

Specimens of the different samples of marble were prepared in the form of cubes of one inch and a half in dimension, and consequently

exhibiting a base of two and a quarter square inches. These were dressed by ordinary workmen with the use of a square, and the opposite sides made as nearly parallel as possible by being ground by hand on a flat surface. They were then placed between two thick steel plates, and in order to insure an equality of pressure, independent of any want of perfect parallelism and flatness on the two opposite surfaces, a thin plate of lead was interposed above and below between the stone and the plates of steel. This was in accordance with a plan adopted by Rennie, and that which appears to have been used by most, if not all, of the subsequent experimenters in researches of this kind. Some doubt, however, was expressed as to the action of interposed lead, which induced a series of experiments to settle this question, when the remarkable fact was discovered that the yielding and approximately equable pressure of the lead caused the stone to give way at about half the pressure it would sustain without such an interposition. For example, one of the cubes precisely similar to another, which withstood a pressure of upwards of 60,000 pounds when placed in immediate contact with the steel plates, gave way at about 30,000 with lead interposed. This interesting fact was verified in a series of experiments, embracing samples of nearly all the marbles under trial, and in no case did a single exception occur to vary the result. The explanation of this remarkable phenomenon, now that the fact is known, is not difficult. The stone tends to give way by bulging out in the centre of each of its four perpendicular faces, and to form two pyramidal figures with their apices opposed to each other at the centre of the cube and their bases against the steel plates.

In the case where rigid equable pressure is employed, as in that of the thick steel plate, all parts must give way together. But in that of a *yielding* equable pressure, as in the case of interposed lead, the stone first gives way along the outer lines or those of least resistance, and the remaining pressure must be sustained by the central portions around the vertical axis of the cube.

After this important fact was clearly determined, lead and all other interposed substances were discarded, and a method devised by which the upper and lower surfaces of the cube could be ground into perfect parellelism. This consists in the use of a rectangular iron frame, into which a row of six of the specimens could be fastened by a screw at the end. The upper and lower surfaces of this iron frame were wrought into perfect parallelism by the operation of a planing machine. The stones being fastened into this, with a small portion of the upper and lower parts projecting, the whole were ground down to a flat surface, until the iron and the face of the cubes were thus brought into a continuous plane. The frame was then turned over, and the opposite surfaces ground in like manner. Care was, of course, taken that the surfaces thus reduced to perfect parallelism, in order to receive the action of the machine, were parallel to the natural bed of the stone.

All the specimens tested were subjected to this process, and in their exposure to pressure were found to give concordant results. The crushing force exhibited was therefore much greater than that heretofore given for the same material.

The commission also determined the specific gravities of the different samples submitted to their examination, and also the quantity of water which each absorbs.

They consider these determinations, and particularly that of the resistance to crushing, tests of much importance, as indicating the cohesive force of the particles of the stone, and its capacity to resist most of the influences before mentioned.

The amount of water absorbed may be regarded as a measure of the antagonistic force to cohesion, which tends, in the expansion of freezing, to disintegrate the surface. In considering, however, the indication of this test, care must be taken to make the comparison between marbles of nearly the same texture, because a coarsely crystallized stone may apparently absorb a small quantity of water, while in reality the cement which unites the crystals of the same stone may absorb a much larger quantity. That this may be so was clearly established in the experiments with the coarsely crystallized marbles examined by the commission. When these were submitted to a liquid which slightly tinged the stone, the coloration was more intense around the margin of each crystal, indicating a greater amount of absorption in these portions of the surface.

The marble chosen for the Capitol is a dolomite, or, in other words, is composed of carbonate of lime and magnesia in nearly atomic proportions. It was analyzed by Dr. Torrey of New York, and Dr. Genth of Philadelphia. According to the analysis of the former it consists in hundredths parts of—

Carbonate of lime	54.621
Carbonate of magnesia	43.932
Carbonate of protoxide of iron	.365
Carbonate of protoxide of manganese (a trace) mica	.472
Water and loss	.610

The marble is obtained from a quarry in the southeasterly part of the town of Lee, in the State of Massachusetts, and belongs to the great deposit of primitive limestone which abounds in that part of the district. It is generally white, with occasional blue veins. The structure is fine grained. Under the microscope it exhibits fine crystals of colorless mica, and occasionally also small particles of bisulphuret of iron. Its specific gravity is 2.8620; its weight 178.87 lbs. per cubic foot; it absorbs .103 parts of an ounce per cubic inch, and its porosity is great in proportion to its power of resistance to pressure. It sustains 23.917 lbs. to the square inch. It not only absorbs water by capillary attraction, but in common with other marble suffers the diffusion of gases to take place through its substance. Dr. Torrey found that hydrogen and other gases, separated from each other by slices of the mineral, diffuse themselves with considerable rapidity through the partition.

This marble, soon after the workmen commenced placing it in the the walls, exhibited a discoloration of a brownish hue, no trace of which appeared so long as the blocks remained exposed to the air in the stonecutter's yard. A variety of suggestions and experiments were made in regard to the cause of this remarkable phenomenon,

and it was finally concluded that it was due to the previous absorption by the marble of water holding in solution a small portion of organic matter, together with the absorption of another portion of water from the mortar.

To illustrate the process let us suppose a fine capillary tube, the lower end of it immersed in water, and of which the internal diameter is sufficiently small to allow the liquid to rise to the top, be exposed to the atmosphere; evaporation will take place at the upper surface of the column, a new portion of water will be drawn up to supply the loss; and, if this process be continued, any material which may be dissolved in the water, or mechanically mixed with it, will be found deposited at the upper orifice of the tube, or at the point of evaporation.

If, however, the lower portion of the tube be not furnished with a supply of water, the evaporation at the top will not take place, and the deposition of foreign matter will not be exhibited, even though the tube itself may be filled with water impregnated with impurities. The pores of the stones, so long as the blocks remain in the yard, are in the condition of the tube not supplied at its lower end with water, and consequently no current takes place through them, and the amount of evaporation is comparatively small; but when the same blocks are placed in the wall of the building, the absorbed water from the mortar at the interior surface gives the supply of the liquid necessary to carry the coloring materials to the exterior surface, and deposit it at the outer orifices of the pores.

The cause of the phenomenon being known, a remedy was readily suggested, which consisted in covering the surface of the stone to be embedded in mortar with a coating of asphaltum. This remedy has apparently proved successful. The discoloration is gradually disappearing, and in time will probably be entirely imperceptible.

This marble, with many other specimens, was submitted to the freezing process fifty times in succession. It generally remained in the freezing mixture for twenty-four hours, but sometimes was frozen twice in the same day. The quantity of material lost was .00315 parts of an ounce. On this data Captain Meigs has founded an interesting calculation which consists in determining the depth to which the exfoliation extended below the surface as the effect of its having been frozen fifty times. He found this to be very nearly the ten thousandth part of an inch. Now, if we allow the alternations of freezing and thawing in a year on an average to be fifty times each, which, in this latitude, would be a liberal one, it would require ten thousand years for the surface of the marble to be exfoliated to the depth of one inch. This fact may be interesting to the geologist as well as the builder.

Quite a number of different varieties of marble were experimented upon. A full statement of the result of each will be given in the reports of the committees.

At the meeting of the Association at Cleveland, I made a communication on the subject of *cohesion*. The paper, however, was presented at the last hour; the facts were not fully stated, and have never been published. I will, therefore, occupy your time in briefly

presenting some of the facts I then intended to communicate, and which I have since verified by further experiments and observations.

In a series of experiments made some ten years ago, I showed that the attraction of the particles for each other of a substance in a liquid form was as great as that of the same substance in a solid form. Consequently, the distinction between liquidity and solidity does not consist in a difference in the attractive power occasioned directly by the repulsion of heat; but it depends upon the perfect mobility of the atoms, or a lateral cohesion. We may explain this by assuming an incipient crystallization of atoms into molecules, and consider the first effect of heat as that of breaking down these crystals and permitting each atom to move freely around every other. When this crystalline arrangement is perfect, and no lateral motion is allowed in the atoms, the body may be denominated perfectly rigid. We have approximately an example of this in cast-steel, in which no slipping takes place of the parts on each other, or no material elongation of the mass; and when a rupture is produced by a tensile force, a rod of this material is broken with a transverse fraction of the same size as that of the original section of the bar. In this case every atom is separated at once from the other, and the breaking weight may be considered as a measure of the attraction of cohesion of the atoms of the metal.

The effect, however, is quite different when we attempt to pull apart a rod of lead. The atoms or molecules slip upon each other. The rod is increased in length, and diminished in thickness, until a separation is produced. Instead of lead we may use still softer materials, such as wax, putty, &c., until at length we arrive at a substance in a liquid form. This will stand at the lower extremity of the scale, and between extreme rigidity on the one hand, and extreme liquidity on the other, we may find a series of substances gradually shading from one into the other.

According to the views I have presented, the difference in the tenacity in steel and lead does not consist in the attractive cohesion of the atoms, but in their capability of slipping upon each other. From this view it follows that the form of the material ought to have some effect upon its tenacity, and also that the strength of the article should depend in some degree upon the process to which it had been subjected.

For example, I have found that softer substances in which the outer atoms have freedom of motion, while the inner ones, by the pressure of those exterior, are more confined, break unequally; the inner fibres, if I may so call the rows of atoms, give way first, and entirely separate, while the exterior fibres show but little indications of a change of this kind.

If a cylindrical rod of lead three quarters of an inch in diameter, turned down on a lathe in one part to about a half of an inch, and then be gradually broken by a force exerted in the direction of its length, it will exhibit a cylindrical hollow along its axis of half an inch in length, and at least a tenth of an inch in diameter. With substances of greater rigidity this effect is less apparent, but it exists even in iron, and the interior fibres of a rod of this metal may be

entirely separated, while the outer surface presents no appearance of change.

From this it would appear that metals should never be elongated by mere stretching, but in all cases by the process of wire-drawing, or rolling. A wire or bar must always be weakened by a force which permanently increases its length without at the same time compressing it.

Another effect of the lateral motion of the atoms of a soft heavy body, when acted upon by a percussive force with a hammer of small dimensions in comparison with the mass of metal. For example, if a large shaft of iron be hammered with an ordinary sledge, the tendency would be to expand the surface so as to make it separate from the middle portions. The interior of the mass by its own inertia becomes as it were an anvil, between which and the hammer the exterior portions are stretched longitudinally and transversely. I here exhibit to the Association a piece of iron originally from a square bar four feet long, which has been so hammered as to produce a perforation of the whole length entirely through the axis. The bar can be seen through as if it were the tube of a telescope.

This fact appears to me to be of great importance in a practical point of view, and may be connected with many of the lamentable accidents which have occurred in the breaking of the axles of locomotive engines. These, in all cases, ought to be formed by *rolling*, and not with the hammer.

The whole subject of the molecular constitution of matter offers a rich field for investigation, and isolated facts, which are familiar to almost every one, when attentively studied, will yield results alike interesting to abstract science and practical art.

DESCRIPTION OF THE OBSERVATORY AT ST. MARTIN, ISLE JESUS, CANADA EAST,

Latitude 45° 32′ *north, longitude* 73° 36′ *west. Height above the level of the sea* 118 *feet. Erected by Charles Smallwood, M. D., L. L. D.*

We preface Dr. Smallwood's own account of his observatory by a sketch of the general appearance of the building and instruments, from the pen of Dr. Hall, published in the Montreal Gazette.

A small wooden building, distant about twenty yards from the dwelling house of Dr. Smallwood, contains the whole of the apparatus which has for so many years furnished such valuable results. A short distance from it, and on a level with the ground, is the snow gauge. Immediately in front of the entrance to the small building is a dial, with an index to point out the course of the clouds. Contiguous to the building again may be seen four erect staffs. The highest of which—80 feet—is intended for the elevation of a lighted lantern, to collect the electricity of the atmosphere, the copper wires from which lead through openings in the roof of the building to a table inside, on which a four-armed insulated conductor is placed. The lantern is made to ascend and descend on a species of railway, in order to obviate all jarring. On another pole is placed the wind vane, which, by a series of wheels moved by a spindle, rotates a dial inside the building marked with the usual points of the compass. Another staff, about 30 feet high, contains the anemometer, or measurer of the force of the wind, which, by a like arrangement of apparatus, is made to register its changes inside. The last pole, 20 feet in height, contains the rain gage, the contents of which are conducted by tubing also into the interior of the building, in which, by a very ingenious contrivance, the commencement and ending of a fall of rain are self-marked.

At the door entrance on the right side is a screened place, exposed to the north, on which the thermometer and wet bulb thermometer are placed, four feet from the surface of the earth. A similar apartment on the left contains the scales with which experiments had been conducted throughout the winter to ascertain the proportional evaporation of ice.

On entering the door, in the centre of the apartment is a transit instrument *in situ*, for the convenience of using which openings are made in the roof, usually kept closed by traps. This apparatus is not the most perfect of its kind, but is amply adequate for all its uses. On the left is a clock, the works of which, by means of a wheel, are made (while itself keeps proper time) to move slips of paper along little railways, on which the anemometer by dots registers the velocity

of the wind; the rain gage, the commencement and end of showers; and the wind vane, the continually shifting currents of wind. This is effected by a pencil kept applied by a spring to a piece of paper on the dial previously alluded to, and as by the clock-work the dial, and the two previously mentioned slips of paper move at the rate of one inch per hour, so it is easy to determine, in the most accurate manner, the direction and force of the wind at any hour of the day, or any

SMALLWOOD'S OBSERVATORY.

period of the hour. Now, with the exception of the clock, the whole of this miniature railway work, with all its apparatus, wheels, &c., &c., is the work of Dr. Smallwood's own hands, and exhibits, on his part, a mechanical talent of the highest order.

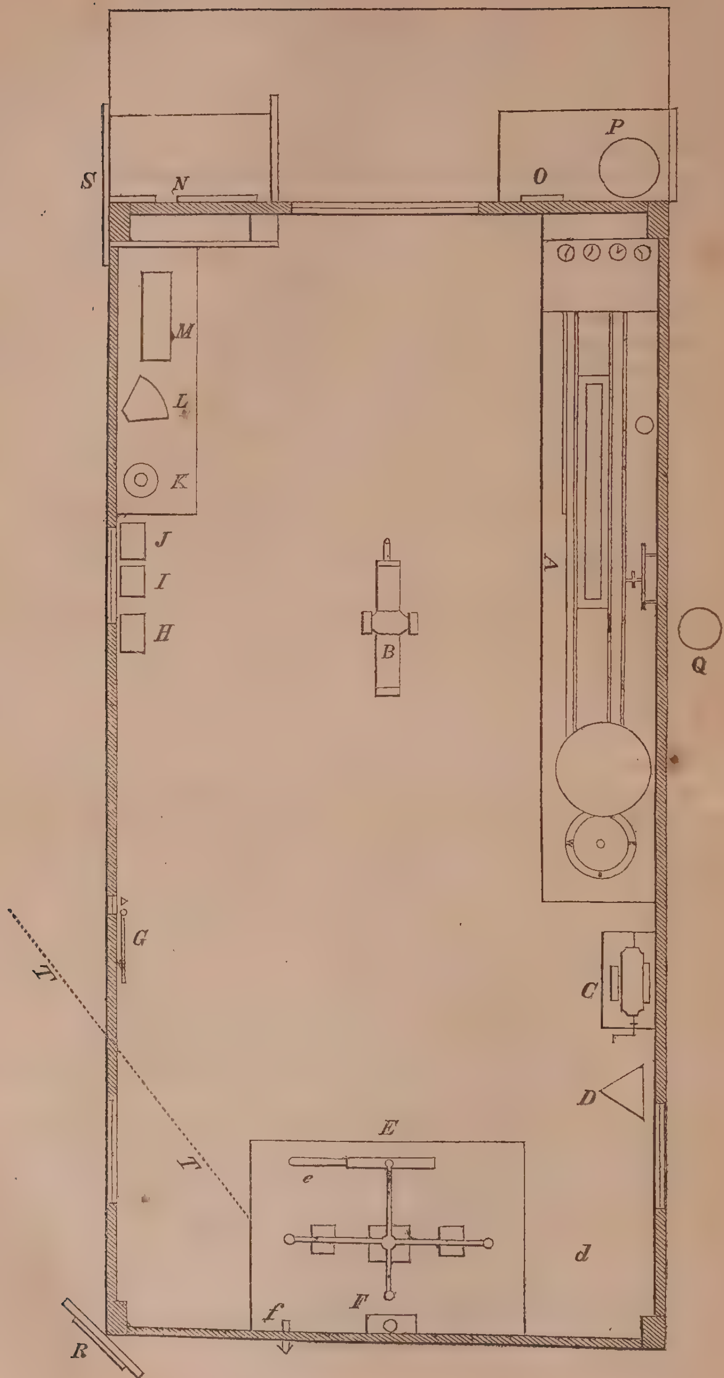
At the extreme end of the room is a table, beneath which is an arrangement for a heating apparatus, and on which is the four arm conductor previously alluded to. To the two lateral and front arms hang, respectively, two of Volta's electrometers, and one of Bennet's, while beneath the knob on the anterior, there is a discharging apparatus, with an index playing over a graduated scale, to measure during thunder storms the force of the electric fluid, by the *length* of its spark. On this subject we cannot avoid a reflection on the fate of the unfortunate Richman. In this case such precautions are adopted as will obviate any casualties whatever; great precaution, however, is required in these experiments, and Dr. Smallwood, fully aware of it, has the whole placed in connexion with the earth by means of a brass chain and iron rod. As another proof of Dr. Smallwood's ingenuity and mechanical skill, we may notice that the whole of this apparatus, even to the electrometers, is the result of his own handicraft; and the whole arrangements in the little room are a signal proof how much a man may do unaided, and how well he can effect an object if thrown entirely upon his own resources.

On the right wall of the apartment are suspended the barometers, of which there are three. 1. A standard of Newman's; 2. Another of Negretti's, but of different construction; and 3d. One of Doctor Smallwood's own construction. The means of the three observations is the measure adopted for the observation.

The only other instrument deserving of notice is the one to determine the terrestrial radiation; and this also has been made by Dr. Smallwood. It consists of a mirror of speculum metal, (composed of copper, zinc, and tin,) of six inches in diameter, and wrought into the form of a parabolic surface, in the focus of which, at the distance of eight feet, a self-registering spirit thermometer is placed. The construction of this was a labor requiring great nicety in execution, and involving the sacrifice of much time; but perseverance even here conquered the difficulties, and we witnessed a mirror whose reflecting powers would not have disgraced Lord Ross' telescope. In fact, placed in a telescope it has, we were informed, proved itself capable of resolving those singular stellar curiosities—the double stars.

Dr. Smallwood certainly deserves great credit for his perseverance in a favorite study, under the most unpromising circumstances; but in nothing is he so remarkable as in that peculiar ingenuity which has led him to overcome difficulties in the prosecution of scientific enquiry, which, to most minds, would have been utterly discouraging.

The Natural History Society of Montreal intend to petition the legislature for a grant of money to enable them to publish Dr. Smallwood's tables of observations for the last twelve years. This is a most laudable measure, and must meet with the support of every man who has the welfare of science and Canada at heart.



PLAN OF THE OBSERVATORY.

EXPLANATION OF EXTERNAL VIEW OF THE OBSERVATORY.

A. Thermometer for solar radiation.

B. Screen of Venetian blinds.

C. Thermometers.

D. Opening in ridge of the roof, closed with shutters, to allow use of transit instrument.

E. Rain gage with conducting pipe through the roof.

F. Velocity shaft of the anemometer.

G. Mast for elevating apparatus for collecting electricity.

H. Cord for hoisting the collecting apparatus.

I. Copper wire for conducting the electricity into the building.

J. Direction shaft of the anemometer.

EXPLANATION OF THE PLAN OF THE OBSERVATORY.

A. Anemometer.

B. Small transit for correcting time

C. Electrical machine for charging the distinguisher.

D. Peltier's electrometer.

d. Space occupied by drosometer, polariscope, &c.

E. Electrometer. e. Discharger.

F. Distinguisher.

f. Small stove—sometimes used in damp weather.

G. Thermometer placed in the prismatic spectrum for investigations in light.

H. Nigretti & Zambra's barometers and cisterns, 118 feet above the level of the sea.

I. Small-tube barometer.

J. Newman's barometer.

K. Aneroid barometer.

L. Quadrant and artificial horizon.

M. Microscope and apparatus for ascertaining the forms of snow crystals.

N. Thermometer, psychometer, &c., 4 feet high. A space is left between the two walls to insure insulation and prevent radiation.

O. Ozonometer.

P. Evaporator—removed in winter and replaced by scales for showing the amount of evaporation from the surface of ice.

Q. Post sunk in the ground, and 40 feet high, to carry the arms of support for the anemometer.

R. Solar radiator.

S. Venetian blinds.

T. Iron rod beneath the surface of the ground connected with the discharger to insure safety.

DESCRIPTION OF THE OBSERVATORY, BY DR. SMALLWOOD.

The observatory is placed in the magnetic meridian, is constructed of wood, and has an opening in the roof, furnished with sliding shutters, for the observations, by means of a transit instrument, of the passage of a star across the meridian for the correction of the clock time. It is also connected by the Montreal telegraph with the principal places in the United States; the wires being led into the observatory. It has also a seven-inch achromatic telescope, the object glass by Frauenhofer, of Munich, and observations are taken on the heavenly bodies as often as there are favorable nights.

Observations are taken on the usual instruments used by meteorologists at 6 and 7 a. m. and at 2, 9, and 10 p. m., daily; also on the temperature of springs and rivers, and the opening and closing thereof; also on the foliation and flowering of plants and trees, and the periodic appearance of animals, birds, fishes and insects beside the usual observations on auroras, halœs, meteors, and any remarkable atmospheric disturbances. Constant tri-daily observations on the amount and kind of atmospheric electricity, ozone and thunder storms, are all recorded. Many of the instruments are self-registering, and to some the photographic process has been adopted.

The observatory is furnished with four barometers. 1. A Newman standard, 0.60 of an inch bore; the brass scale extends from the cistern to the top of the tube, and is adapted for registration by the photographic process. 2. A Nigretti and Zambra's tube, 0.30 of an inch bore; another of a small bore, and also an aneroid. The cisterns are all placed at the same height (118 feet,) and are read at each observation.

Thermometers of Sixes, Rutherford, Nigretti, &c., &c.

The *psychrometer* consists of two thermometers whose readings are coincident. There is also a Saussure's hygrometer.

For *solar radiation* a maximum Rutherford thermometer is used, with the bulb kept blackened with Indian ink; the tube is shaded by a piece of glass blackened also with Indian ink, which prevents the index from adhering to either the tube or the mercury, which is often the case when not shaded.

Terrestrial radiation is indicated by a spirit thermometer of Rutherford, which is placed in the focus of a parabolic mirror 6 inches in diameter and of 100 inches focus.

Drosometer or dew measurer.—*One* is of copper, like a funnel, the inside of which has been exposed to the flame of a lamp and has become coated with lamp black; the other is a shallow tin dish, painted black, and ten inches in diameter.

Rain-gage.—The reservoir is thirteen inches in diameter, and is placed 20 feet above the soil. It is self-registering, and is attached to the anemometer.

The snow-gage presents 200 inches of surface. A tin tube, 3 inches in diameter and 10 inches long, is used for obtaining snow for the purpose of reducing the amount to the relative amount of water. The tin tube fits in another vessel of tin of the same diameter, and the snow is easily reduced and measured.

The evaporator exposes a surface of 100 inches; the amount of evaporation from the surface of ice is measured during the winter months.

The *ozonometers* are Schonbien's & Moffat's, one is raised to the altitude of 80 feet.

A *microscope* and apparatus for the examination of snow crystals, and obtaining copies by the chromotype process.

The electrical apparatus.—This consists of three parts: a hoisting a collecting and a receiving apparatus.

The hoisting apparatus consists of a pole or mast 80 feet high. It is in two pieces, but is spliced and bound with hoop iron, and squared or dressed on one face for about six inches. It is dressed in a straight line to receive cross pieces of 2-inch plank, 8 inches wide and 12 inches long, which are firmly nailed to the mast or pole about three feet apart; this serves as a ladder to climb the pole in case of necessity. Each of these cross pieces is *rebated* to receive pieces of inch board, 4 inches wide, and placed edgeways in the *rebate*, extending from the top to the bottom of the pole, and forms a sort of vertical railway; these pieces are also grooved or rebated to receive a slide, which runs in these grooves and carries the receiving apparatus. From the top of the sliding piece passes a rope over a pulley fixed at the top of the mast, and from it to a roller and windlass, by which means the collecting lantern is raised or lowered for trimming the lamps. I have also used it for the purpose of placing an ozonometer at that height (80 feet.) The lower part of the mast or pole is fixed into a cross piece of heavy timber, and is supported by 4 stays. These cross timbers are loaded with stones, and are thus rendered sufficiently firm.

The collecting apparatus consists of a copper lantern 3 inches in diameter, 5 inches high.—(See top of mast G, fig. 1. The bottom is moveable and the lamp is placed in it by the means of a small copper pin passing in a slit, which is a very easy method of fixing it. This lantern is placed on the top of a copper rod of ¾ inch thick and 4 feet long; the bottom of the lantern having a piece of copper tube fixed to it, a very little larger than the rod, and is thus easily removed and replaced. To the lower end of the copper rod is soldered an inverted copper funnel, a *parapluie*, for protecting the glass insulating pillar upon which it is fixed by means of a short tube firmly soldered to the underside of the *parapluie*. This glass pillar passes into and is fixed firmly into a wooden box, and is freely exposed to the heat of a second lamp, which is placed in this box and is trimmed at the same time as that in the collecting lantern, and keeps warm and dry the glass pillar, and by that means securing a more perfect insulation. From this upright rod and collecting apparatus descends a thick copper wire, which serves to convey the accumulated electricity to the receiver which is placed in the observatory.

The receiver consists of a cross of brass tubes (gas tubes), each about 2 feet long, and is screwed into a large tube which fits upon a glass cone, which is hollow, forming a system of hollow pipes for the passage of the heat internally, and keep up a certain amount of dryness and consequent insulation. The glass cone is fixed upon a table

over an opening made in it, fitting to the hollow part of the cone. Immediately under this table is placed a small stove of sheet-iron, about 8 inches in diameter, is made double, the space of about 1 inch being left between the two chambers; and I have found this plan very good to effect a good insulation by keeping the whole of the apparatus warm and dry. Charcoal is used as fuel, and is, I think, preferable to a lamp. A coating of suet or tallow is applied to the glass cones or pillars. Care must be taken not to rub or polish the collecting apparatus as it seems to deteriorate its power of collecting and retaining atmospheric electricity; and I have found that its collecting powers increase with its age. Suspended from these cross arms hang the *electrometers*. 1. *Bennet's electroscope* of gold leaves; this scarcely needs a description. 2. *Voltas' electrometer No.* 1, consisting of two straws 2 French inches long; a very fine copper wire passes through these straws which are suspended from the cross arms. This electrometer is furnished with an ivory scale, the old French inch being divided in 24 parts, each being 1°; this forms the standard scale for the amount of tension. 3. *Voltas' electrometer No.* 2 is similar to the No. 1, but the straws are five times the weight of No. 1, so that one degree of Voltas' No. 2 is equal to five of No. 1. *Henly's electrometer* is a straw suspended and furnished with a small pith ball; each of the degrees of Henly's is equal to 100° of No. 1 of Voltas. These electrometers are all suspended from the cross arms. *A discharging apparatus*, furnished with a long glass handle, measures the length of the spark, and serves also as a conductor to carry the electricity collected to the earth, and is also connected by a chain and iron rod passing outside of the observatory for about 20 yards and buried under ground.

Various forms of *distinguishers* are used to distinguish the kinds of electricity. The Voltas electrometers may be rendered self-registering with great facility by the photographic process, by placing a piece of the photographic paper behind the straws and throwing the light of a good lens upon them; the expansion is easily depicted and serves well for a night register. There is also a Peltier's electrometer, and another form of electrometer, consisting of two gold leaves suspended to a rod of copper 2 feet long; the upper end being furnished with a wire box, in which is kept burning some rotten wood, (*touch-wood*.)

The anemometer consists of a *direction shaft* and a *velocity shaft;* to the top of the direction shaft is placed the vane, which is 18 feet in length. The shaft is made of three pieces, to insure lightness and more easy motion; each piece is connected by means of small iron-toothed wheels. The two shafts are six feet apart, and work on cross arms from a mast firmly fixed in the ground. The vane passes some 6 or 8 feet above the velocity shaft, and does not in any way interfere with the other movements. The lower extremities of these shafts are all furnished with steel points, which work on an iron plate or a piece of flint, and pass through the roof of the observatory; the openings being protected by tin parapluies fixed to the shaft and revolving with them. Near the lower extremity is placed a toothed wheel 8 inches in diameter, which is connected to another wheel of the same diameter, which carries upon its axis a wooden disc 13 inches in dia-

meter, upon which is clamped a paper register (old newspapers answer very well) washed over with whiting and flour paste. Upon the surface of this register is traced by a pencil the direction of the wind; this register is renewed every twelve hours.

The *velocity* shaft is in two pieces, connected by means of the toothed wheels and steel pivots, as in the direction shaft; and, practically, the friction is *nil*. At the top of the velocity shaft is fixed three hemispherical tin or copper caps, 10 inches in diameter, similar in construction to those of the Rev. Dr. Robinson's, of Armagh, and are firmly riveted to three iron arms of ⅝-inch iron. These caps revolve always in the same direction, and one revolution is found to be just one-third of the linear velocity of the wind. I have no reason to doubt Dr. Robinson's formula for this calculation. At the lower extremity of the velocity shaft is fixed a one-toothed wheel 2¾ inches in diameter; this moves a second, or ten-toothed, wheel, which also gives movement to a third wheel, which marks a hundred revolutions of the caps, which are so calculated that each one hundred revolutions are equal to one mile linear, and whenever one hundred revolutions have been accomplished a small lever is elevated by means of a small inclined plane, which is fixed upon the edge of the last wheel, and which gives motion to the level. The other extremity of the lever is furnished with a fine steel point, which dots off, upon a paper register, the miles as they pass. This register is of paper one and a quarter inch wide, and is removed every twelve hours.

Between the two shafts at the lower extremities is placed two runners of wood *rebated* to receive a slide or train which carries the register. To the underside of this slide is fixed a rack and is moved by a pinion, the movement of which is communicated by a clock, the cord of the weight being passed over a wheel and pulley and advances one inch per hour, and the lever before described dots off the miles as the register advances under the steel point; it does in this manner show the increase and decrease of the velocity, and also the moment of its change. Attached to this moveable train is a rod of wood carrying a pencil, which passes over the disc connected with the direction shaft, and there traces, as it advances, the direction of the wind and the moment of its changes, and the point from which it veered. The extreme height of the vane is 40 feet, which might be increased if required. The clock is wound up every twelve hours, which brings back the train to its starting point.

There is also a polariscope and prism for experimenting on the various rays of light in connexion with photography and the germination of seeds.

The observatory also possesses a quadrant and artificial horizon, and also apparatus for the measure of haloes, and registering dial for the direction and course of the clouds.

ON THE RELATIVE INTENSITY OF THE HEAT AND LIGHT OF THE SUN UPON DIFFERENT LATITUDES OF THE EARTH.

BY L. W. MEECH.

The ninth volume of the Smithsonian Contributions to Knowledge contains a memoir, which, under the above title, presents the astronomical determinations of the relative number of heating and illuminating rays received from the sun upon any portion of the exterior surface of the earth. During their passage through the air in impinging upon the solid earth, the rays are modified by a variety of circumstances; still the primary intensity of the sun is the controlling cause of the changes of temperature of the seasons, and therefore the determination of its laws has a special importance.

The subjoined account, with slight additions, contains nearly all of the paper referred to, except the mathematical portions, for which reference may be made whenever necessary to the original memoir.

The regular and almost uniform variations which meteorological tables exhibit, indicate a periodical cause of change, which evidently resides in the sun. The inquiry then arises, may not these variations be determined by theory from the apparent course of the sun?

The object of the investigation here presented is to resolve the problem of solar heat and light, to the extent of the principle, that the intensity of the sun's rays, like gravitation, varies inversely as the square of the distance, without resorting to any other hypothesis. The principle is but a geometrical consequence of the divergence of the rays. This elementary view thus presents the sun shining upon a distant planet, and indicates the sum of the intensities received at the planet's surface in all its various phases of position and inclination.

In relation to the earth especially, the sum of the intensities must be referred to the exterior limit of the atmosphere which surrounds the globe. This condition, which is perhaps necessary in the present state of science, has the advantage of rendering the deductions as rigorously accurate as are the propositions of geometry and the conic sections.

Poisson, in 1835, observed that, "for the completion of the theory of heat, it is necessary that it should comprise the determination of the movements produced in aeriform fluids, in liquids and even in solid bodies; but geometers have not yet resolved this order of questions, of great difficulty, with which are connected the phenomena of

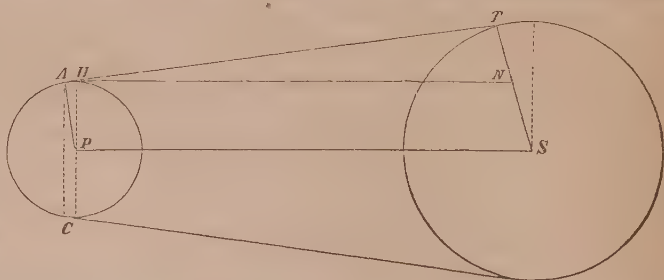
the trade-winds, of certain currents observed in the sea, and the diurnal variations of the barometer." The subject is believed to be now included among the prize questions of the French Academy, and in the increasing number of researches it is hoped that its difficulties may at length be effectively obviated.

The laws of Solar Intensity here derived *à priori*, have a general accordance with physical phenomena, and will furnish instructive comparisons with analogous values obtained by meteorological observations. The changes of the sun's intensity upon the inaccessible regions of the Pole will be included, to which the late Arctic explorations have given unusual interest. And, among other advantages, light will be thrown upon geological researches relating to changes of the heat of the globe at very remote epochs.

At the close, the course of investigation has led to the development of a pecular inequality in the annual duration of sunlight. The like series of values for the duration of twilight is also new, and will not be devoid of interest. But the main design has been—distinguishing between the sun's intensity and terrestrial temperatures—to carry out one comprehensive principle, by which the laws of the sun's intensity of heat and light are obtained to some degree of completeness as a system.

SECTION I.

Irradiated surface upon the planets.—It is evident that the extreme rays proceeding from the sun to the planet are tangent to the two spheres, as shown in the annexed diagram; where are represented a section of the sun, of the planet, and the radius-vector or distance of the planets centre from that of the sun. The sun being the greater body



illuminates not only the adjacent hemisphere of the planet, but also the zone or belt A C lying beyond, which may be called *the zone of differential radiation*. From the geometrical properties of the figure, it is shown that the sine of the angular breadth of the zone of differential radiation is equal to the difference of the radii of the sun and planet divided by the radius-vector of the planet's orbit.

With this principle, we can determine by geometry the actual breadth in miles, and the proportions of dark and illuminated surface. These will vary with the elliptic changes of distance from the sun, as indicated in the following table.

PLANET.	Average breadth of zone.	Greatest breadth of zone.	Least breadth of zone.	Proportion of surface irradiated.
	Miles.	*Miles.*	*Miles.*	
Mercury	17.89	22.32	14.96	.505991
Venus	61.12	61.54	60.70	.503190
Earth	18.29	18.60	17.98	.500231
Mars	6.42	7.07	5.87	.500152
Vesta	.26	.28	.24	.500980
Jupiter	34.87	36.62	33.28	.500404
Saturn	18.17	19.25	17.21	.500222
Uranus	4.01	4.20	3.83	.500117
Neptune	6.14	6.19	6.08	.500087

In obtaining these tabular results, the earth's mean distance from the sun was taken at 95,273,870 miles, and its radius at 3,962 miles.

It will be perceived that the vast *magnitude* of the sun brings advantages of temperature and sunlight similar to those which the preponderance of its *mass* gives to the steadiness and uniformity of the planetary revolutions. Were the same amount of heat and light radiated from a smaller body like the moon, the effects would be restricted to a smaller portion of the earth's surface; and the zone of differential radiation would be reversed to one of cold and darkness. But in the present beneficent arrangement, light and heat preponderate, counteracting extremes of heat and cold with a warmer temperature. And this effect is further prolonged by atmospheric refraction and reflection of the rays, which, rendering the transitions more mild and gradual, lessens the reign of night.

To estimate the effect of the *Refraction of Light*, we have only to find two points on the spherical surface of the earth, at such distance that the inclination of the two tangent rays from the sun falling on them shall be just equal to the horizontal refraction; that is, suppose the sun's upper margin or limb to be in the horizon, sending without refraction a level beam of rays to the observer. In consequence of horizontal refraction in the atmosphere, the rays will appear to come from a source 34′ higher in altitude. And being inclined at this angle with the unrefracted rays, they will pass over, and become tangent to a point of the earth's surface 34′ of terrestrial arc behind the former. The terrestrial radii drawn to these points will evidently be inclined at the same angle as their tangents, which is 34′ nearly, corresponding to a distance on the surface of 40 English miles. Thus it appears that the effect of refraction in widening the irradiated zone of the earth is more than twice as great as that arising from the apparent semi-diameter, or the mere size of the sun. Uniting the two effects, the sun is found to illuminate more than half of the earth's surface by a belt or zone that is 58 miles in width, encircling the seas and continents of the globe.

The advantage of the vast size of the sun is most conspicuous upon the planet Venus, our evening and morning star, where the belt of illumination is sixty-one miles in width, as shown in the preceding table. The next in rank is Jupiter, whose belt of greater illumina-

tion is thirty-five miles wide; while those of Mercury, the earth, and Saturn, are nearly eighteen miles in breadth. In the last column of the table, it will be observed that the asteroid Vesta, though situated beyond Mars, yet has, in consequence of its smaller size, a greater proportion of illuminated surface than the earth.

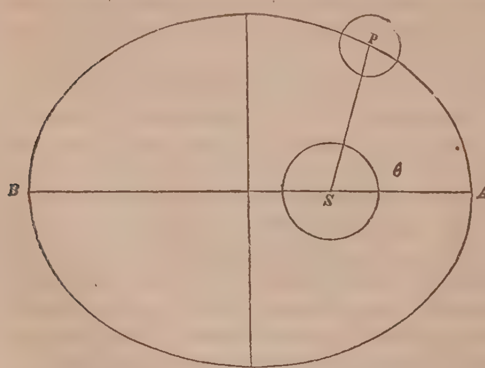
By computation it is found that the zone of differential illumination upon the earth extends over 455,400 square miles; or, including the additional area due to 34′ horizontal refraction, it comprehends an aggregate of 1,430,800 square miles of surface. The position of this great zone is continually changing, and in turn it overspreads every island, sea, and continent. At the vernal equinox, when the sun is vertical to the equator, it will readily be perceived that the larger base of this zone is a great circle passing through the poles and having the earth's axis for its diameter. From this position it gradually diverges, till at the summer solstice one extremity of its diameter will be in the Arctic, and the other in the Antarctic circle. Thence it gradually returns to its former position at the poles at the autumnal equinox, all the while revolving in every twenty-four hours, like a fringed circle around the globe, and accompanied with the lustrous tints and shadows which variegate the dawn and close of day.

SECTION II.

LAW OF THE SUN'S INTENSITY UPON THE PLANETS IN RELATION TO THEIR ORBITS.

THE preceeding section represents the sun's action upon a distant planet at a given distance, or at rest. It is here proposed to examine the effect when the distance is variable; that is, supposing the planet to commence its motion from a state of rest, in an elliptical orbit, to determine the intensity received during its passage through any part, or the whole of its orbit.

In the annexed figure, let S denote the sun situated in one focus; P the planet's position at a given time; A, the perihelion or point in the orbit nearest the sun, B, the aphelion or point farthest from the sun, SP, the radius-vector, and the angle $A\ S\ P$ the true anomaly. From the property of the ellipse, combined with the principle that heat and light vary inversely as the square of the distance, it is proved that in its orbital motion the earth does not receive equal increments of heat and light in equal times; but *the amount received in any given interval is exactly proportional to the true anomaly or true longitude described in that interval.* This important law, or one less correct, for the mean longitude, appears to have been first published in the Pyrometry of Lambert.



This point being established, let us, in the next place, compare the intensities received by the planets during *entire revolutions* in their orbits; and also the ratios of intensity *for equal times*, which depend simply on the inverse square of the distance. The following table has been thus prepared from the usual astronomic elements.

The sun's relative intensity upon the principal planets.

Planet.	In a whole revolution.	In equal times at the:		
		Mean distance.	Perihelion.	Aphelion.
Mercury	1.643	6.677	10.573	4.592
Venus	1.176	1.911	1.937	1.885
Earth	1.000	1.000	1.034	0.967
Mars	.813	.431	0.524	0.360
Jupiter	.439	.037	.041	.034
Saturn	.324	.011	.012	.010
Uranus	.228	.003	.003	.003
Neptune	.182	.001	.001	.001

It should be observed that the foregoing table does not take account of the different dimensions of the planets, but refers to a unit of plane surface upon their disks, which is exposed perpendicularly to the rays of the perpetual sun. Upon the disk of Mercury, the solar radiation appears to be nearly seven times greater than on the earth; while upon Neptune, it is only as the one-thousandth part, in equal times. In entire revolutions, however, the intensities received will be seen to approach more nearly to equality.

The intensities are thus unequal; and, by a calculation founded on the apparent brightness of the planets as estimated by the eye, Prof. Gibbes has shown, in the Proceedings of the American Association for the Advancement of Science for 1850, that the reflective powers are also greater, according as the several planets are more distant from the sun.

Another feature worthy of mention, is the resemblance of the earth to the planet Mars; upon which Sir W. Herschel has remarked: "The analogy between Mars and the earth is, perhaps, by far the greatest in the whole solar system. The diurnal motion is nearly the same, the obliquity of their respective ecliptics not very different; of all the superior planets, the distance of Mars from the sun is by far the nearest alike to that of the earth; nor will the length of the Martial year appear very different from what we enjoy, when compared to the surprising duration of the years of Jupiter, Saturn, and Uranus. If we then find that the globe we inhabit has its polar region frozen and covered with mountains of ice and snow, that only partly melt when alternately exposed to the sun, I may well be permitted to surmise that the same causes may have the same effect on the globe of Mars; that the bright polar spots are owing to the vivid reflection of light from frozen regions; and that the reduction of those spots is to be ascribed to their being exposed to the sun."

From this investigation it appears that during each of the four astronomic seasons of spring, summer, autumn, and winter, the intensities received from the sun are precisely equal. For in each season the earth passes over three signs of the zodiac, or a quadrant of longitude. The equality of intensities, however, applies to the entire globe regarded as one aggregate, and is consistent with local alternations, by which it is summerin the northern hemisphere when it is winter in the southern. Deferring the consideration of these local inequalities, however, we may here illustrate the connexion of the seasons with the elliptic motion from an ephemeris. In the year 1855, for example, spring in the northern hemisphere, commencing at the vernal equinox, March 20th, lasts eighty-nine days; summer, beginning at the summer solstice June 21, continues ninety-three days; autumn, commencing at the equinox, September 23, continues ninety-three days; and winter, beginning at the winter solstice, December 22, lasts ninety days; yet, notwithstanding their unequal lengths, the amounts of heat and light which the whole earth receives are equal in the several periods. Since the earth is not strictly a sphere, but an oblate spheroid, it evidently presents its least section perpendicular to the rays of the sun at the equinoxes. As the sun's declination increases, the section also increases and attains its limit at the solstice. The variation, however, appears to be not material, and compensates itself in each season.

At the present time the earth is in perihelion, or nearest the sun about the 1st of January, and furthest from the sun on the 4th day of July. A special cause must, therefore, be assigned for the striking fact which Professor Dove has shown by comparison of temperatures observed in opposite regions of the globe, namely: that the mean temperature of the habitable earth's surface in June considerably exceeds the temperature in December, although the earth in the latter month is nearer to the sun. This result is attributed by that meteorologist to the greater quantity of land in the northern hemisphere exposed to the rays of the sun at the summer solstice in June; while the ocean area has less power for this object, as it absorbs a large portion of the heat into its depths. Had land and water been equally distributed, in other words, were the earth a homogeneous sphere, the alleged inequality of temperature, it is obvious, would never have existed.

SECTION III.

LAW OF THE SUN'S INTENSITY AT ANY INSTANT DURING THE DAY.

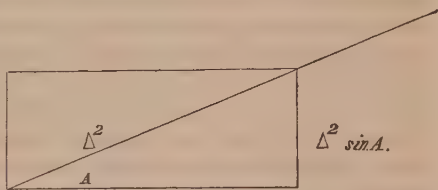
The rays which emanate from the sun's disk into space proceed in diverging lines in the same manner as if they issued directly from the centre. And on arriving at the earth their intensity, as before stated, will be inversely proportional to the square of the distance.

But the more obvious phenomena of solar heat and light are manifested to us under a secondary law. The sun's intensity first becomes sensible in the eastern rays of morning; it gradually increases to a maximum during the day; it declines on the approach of the shades

of evening, and becomes discontinuous during the night. On the morning following the same course is renewed, and continued successively through the year. Ordinary sensation and experience lead us to associate the degree of solar heat, at any part of the day, with the apparent height which the sun has then attained above the horizon. Indeed, theory determines that *the sun's intensity is proportional to the length of a perpendicular line from the sun to the plane of the apparent horizon; that is, it varies as the sine of the sun's altitude.*

The reason of this secondary law will be understood by regarding the beam of solar rays which traverses in a line from the sun to the observer, to be resolved, according to the parallelogram of forces, into a horizontal and a vertical component. The horizontal component running parallel to the earth's surface is regarded as inoperative, while the vertical component measures the direct heating effect.

This relation is more fully shown in the annexed figure, where A denotes the sun's apparent altitude above the horizon. The sun's intensity or impulse in an oblique direction will be measured by the inverse square of the distance, or the direct square of the sun's apparent semi-diameter $\triangle$. If, therefore, $\triangle^2$ denotes the intensity of the rays in a straight line from the sun, $\triangle^2$ *sin A, will be the vertical component or heating force of the rays.* And these terms being in ratio as 1 to *sin A*, the latter component will be represented by a perpendicular line from the sun's centre to the horizon.



Instead of thus decomposing the intensity after the manner of a force in mechanics, as first proposed by Halley, in 1693, the same law may be obtained in an entirely different way from the principle of the inverse square of the distance. The latter mode appears to present it in a more evident light, and was suggested in the original beginnings of the present investigation, which were published in Silliman's *Journal of Science* for the year 1850.*

The intensity at a fixed distance being as the sine of the altitude,

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*Let L = the "apparent" latitude of the place,
D = the sun's meridian declination,
$\triangle$ = the sun's apparent semi-diameter,
A = the sun's altitude, and
H = the hour-angle from noon.

The horizontal section of a cylindrical beam of rays from the sun's disk upon a plain on the earth's surface, is well known to be an ellipse; and if 1 denote the sun's radius, 1 will likewise denote the semi-conjugate axis of this projected ellipse; while the horizontal projection, $\frac{1}{\sin A,}$ will be the semi-transverse axis. The area of the elliptic projection is, therefore, $1 \times \frac{1}{\sin A,} \times \pi$. But the intensity of the same quantity of heat being inversely as the space over which it is diffused, the reciprocal of this area, or *sin A*, on rejecting the constant π, will express the sun's heating effect, supposing the distance to be constant for the same day. But, on comparing one day with another, the intensity further varies inversely as the square of the distance, that is, directly as the square of the apparent diameter or semi-dia-

it follows that the sun shining for sixteen hours from an altitude of 30°, would exert the same heating effect upon a plain as when it shines during eight hours from the zenith; since *sin* 30° is 0.5, and *sin* 90° is 1. At least, such were the result independently of radiation from the earth.

By some writers, the measure of vertical intensity, as the sine of the sun's altitude, has been stated without limitation. Approximately it may apply at the habitable surface of the earth, when the influence of the atmosphere is neglected; yet it is strictly true only at the exterior of the atmospheric envelope which encompasses the globe, or at the outer limit where matter exerts its initial change upon the incident rays.

The distinction here explained has not only engaged the attention of the most eminent meteorologists of modern times, but was equally adopted in ancient philosophy, as appears in the following passage fram Plato's Phædon, LVIII: "For around the earth are low shores, and diversified landscapes and mountains, to which are attracted water, the cloud, and air. But the earth, outwardly pure, floats in the pure heaven like the stars, in the medium which those who are accustomed to discourse on such things call ether. Of this ether, the things around are the sediment which always settles and collects upon the low places of the earth. We, therefore, who live in these terraqueous abodes, are concealed, as it were, and yet think we dwell above upon the earth. As one residing at the bottom of the sea might think he lived upon the surface, and, beholding the sun and stars through the water, might suppose the sea to be heaven. The case is similar, that through imperfection we cannot ascend to the highest part of the atmosphere, since, if one were to arrive upon its upper surface, or becoming winged, could reach there, he would on emerging look abroad, and, if nature enabled him to endure the sight, he would then behold the true heaven and the true light."

In modern times, the researches of Poisson led him to the philosophic conclusion now generally received, that the highest strata of the air are deprived of elasticity by the intense cold; the density of this *frozen* air being extremely small, *Théory de la Chaleur*, p. 460. An atmospheric column resting upon the sea may thus be regarded as an elastic fluid terminated by two liquids, one having an ordinary density and temperature, and the other a temperature and density excessively diminished.

Although the sun's intensity, which is here the subject of investigation, is the principal source of heat, yet its effects are modified by proximate causes of climate, of which the following nine are enumerated by Malte Brun:

1st.—Action of the sun upon the atmosphere.

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meter of the disk. Hence, generally, $\Delta^2 \sin A$, expresses the sun's intensity at any given instant during the day.

To determine the value of *sin A* by spherical trigonometry, the sun's angular distance from the pole, or co-declination, the arc from the pole to the zenith, or co-latitude, and the included hour-angle from noon are given to find the third side or co-altitude. Writing, therefore, sines instead of the co-sines of their complements,

$$\sin A = \sin L \sin D + \cos L \cos D \cos H.$$
$$\Delta^2 \sin A = \Delta^2 \sin L \sin D + \Delta^2 \cos L \cos D \cos H.$$

7th.—The interior temperature of the globe.
8th.—The elevation above the level of the ocean.
9th.—The general inclination of the surface and its local exposures.
10th.—The position of mountains relative to the cardinal points of the compass.
11th.—The neighborhood of great seas and their relative extent.
12th.—The geological nature of the soil.
13th.—The degree of cultivation and of population to which a country has arrived.
14th.—The prevalent winds.

[illegible]

With respect to the general climatic features of the globe, the following points have been ascertained from numerous observations. At an equal distance from the equator, Asia has a comparatively cold winter and a hot summer; Europe [illegible]; America [illegible].

SECTION IV.

[illegible]

In the last section, the sun's vertical intensity upon a given point of the earth's surface at any instant during the day, was shown to be measured by a perpendicular drawn from the centre of the sun to the plane of the horizon. If perpendiculars be thus let fall at every instant during an hour, the sum of the perpendiculars will evidently represent the sum of the vertical intensities received during the hour, which sum may be termed the hourly intensity.

The integral calculus furnishes a ready method of obtaining this sum. For during any one day the sun's distance, [illegible] and the position [illegible] may be regarded as constant, [illegible]

[illegible]

[illegible]

[illegible]

The following cases under the general formula may here be specified:

First, at the time of the *equinoxes*, the sun's daily intensity for all places on the earth is *proportional to the cosine of the latitude.* As the equinoxes in March and September lie intermediate between the extremes or maxima of heat and light in summer, and their minima in winter, the presumption naturally arises that the same expression will approximate to the mean annual intensity. The coincidence is accordingly worthy of note, that the best empirical expression now known for the annual temperature in degrees Fahrenheit, given by Sir David Brewster, in the *Edinburgh Philosophical Transactions*, Vol. IX, is $81°.5 \cos L$, being also proportional to the cosine of the latitude. It is remarkable that Fahrenheit, in 1720, should have adjusted his scale of temperature to such value, that this formula applies, without the addition of a constant term.

Secondly, for all places on the *equator* the latitude is 0; and the sun rises and sets at six, the year round, exclusive of refraction. Consequently the sun's diurnal intensity varies slowly from one day to another, being *proportional to the cosine of the meridian declination of the sun.*

Thirdly, at the *north pole*, the sun rises only at the vernal equinox in March, and continues wholly above the horizon, till it sets at the autumnal equinox. Thus, to either pole, the sun rises but once, and sets but once in the whole year, giving nearly six months day, and six months night. Now suppose the six months day to be divided into equal portions of twenty-four hours each, then *the intensity during twenty-four hours of polar day is proportional to the sine of the declination at the middle of the day.*

Fourthly, at the summer solstice, when the intensity on the pole is a maximum, the ratio becomes as 1 to 1.25; or the polar intensity is one-fourth part greater than on the equator. The difference evidently arises from the fact that daylight in the one place lasts but twelve hours out of twenty-four, while at the pole the sun shines on through the whole twenty-four hours.

It were interesting to find when this polar excess begins and ends, which is ascertained to be on May 10th, and again on August 3d. Therefore, *during this long interval of eighty-five days, comprehending nearly the whole season of summer, the sun's vertical intensity over the north pole is greater than upon the equator.* To this subject we shall again recur in a subsequent section.

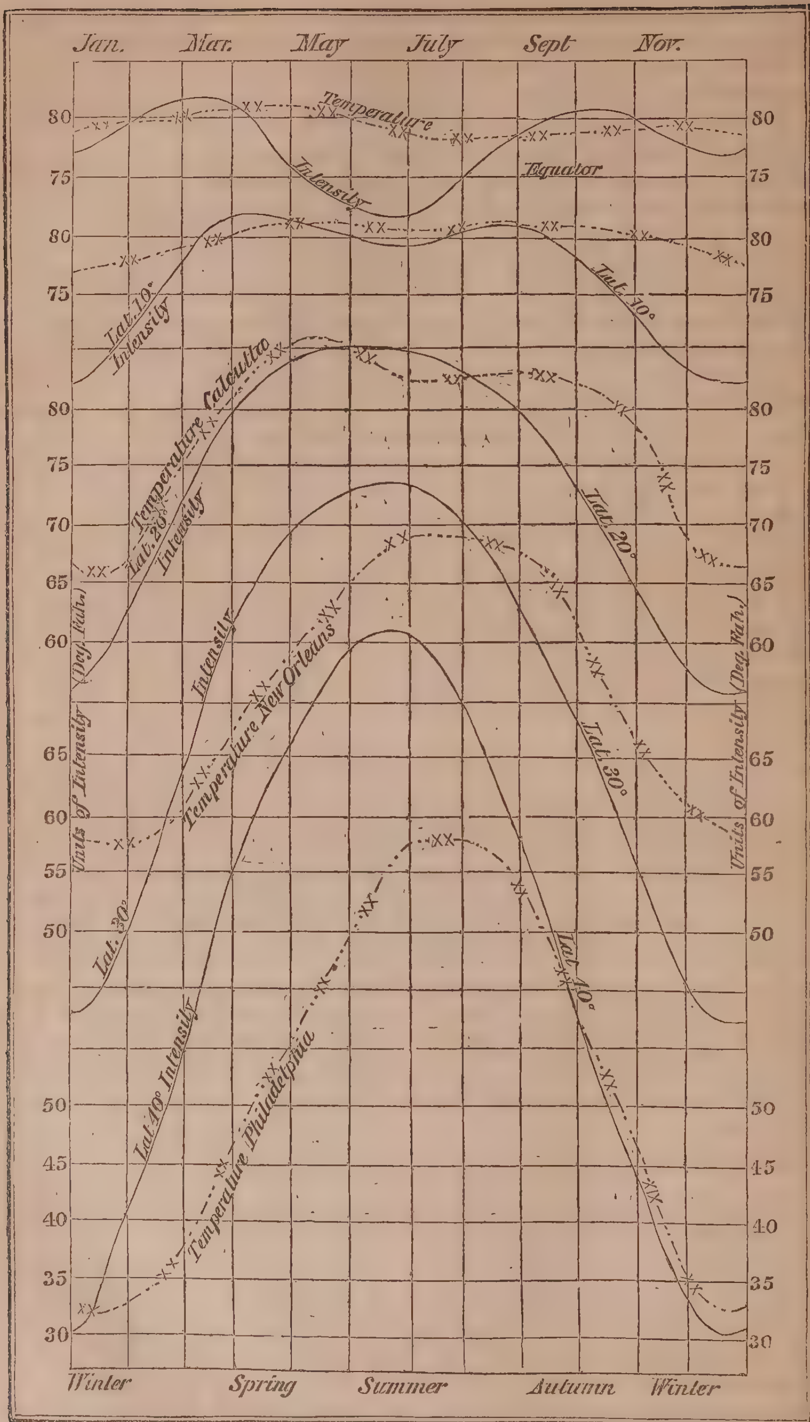
Fifthly, having glanced at these particular cases, let a more complete survey be made for the northern hemisphere. And the same will equally apply to the southern hemisphere, allowing for the reversal of the seasons and change of the sun's distance.

The subjoined table has been computed for intervals of fifteen days, and expresses the results in *units of intensity*. The choice of a *unit* being entirely arbitrary, the intensity of a day on the equator at the time of the vernal equinox is here assumed to be 81.5, and other values are expressed in that proportion. In the last three columns for the frigid zone, the braces include values for the days when the sun shines through the whole twenty-four hours; the blank spaces indicate periods of constant night.

The sun's diurnal intensity at every ten degrees of latitude in the northern hemisphere.

A. D. 1853.	Latitude 0°.	Latitude 10°.	Latitude 20°.	Latitude 30°.	Latitude 40°.	Latitude 50°.	Latitude 60°.	Latitude 70°.	Latitude 80°.	Latitude 90°.
Jan. 1	77.1	67.2	55.8	42.8	30.1	16.5	5.1	------	------	------
Jan. 16	78.1	68.9	58.2	45.8	32.7	19.3	7.2	------	------	------
Jan. 31	79.6	71.7	61.9	49.7	38.6	25.0	11.9	1.4	------	------
Feb. 15	81.0	74.7	66.6	55.6	45.1	31.9	19.0	6.4	------	------
Mar. 2	81.6	78.0	71.3	62.9	52.7	41.1	27.9	14.5	2.1	------
Mar. 17	82.0	80.2	76.0	69.6	61.1	50.2	37.1	25.5	11.6	------
April 1	80.8	81.4	79.5	75.6	68.9	60.2	49.9	38.0	25.6	20.5
April 16	79.0	81.7	82.0	79.5	75.1	68.6	61.1	51.4	44.0	44.6
May 1	76.9	81.5	83.7	83.6	80.8	77.1	70.9	64.6	64.3	65.3
May 16	74.7	80.8	84.7	86.7	85.7	83.3	79.7	76.8	80.3	81.5
May 31	73.0	80.1	85.1	87.8	88.9	87.8	85.7	86.8	91.0	92.4
June 15	72.0	79.6	85.2	88.4	90.1	89.9	88.8	91.7	96.1	97.6
July 1	72.0	79.5	85.0	88.5	90.4	89.5	88.4	90.8	95.1	96.6
July 16	73.0	79.8	84.7	87.5	87.6	86.5	84.1	84.3	88.3	89.7
July 31	74.7	80.4	83.9	85.1	84.5	81.6	77.3	73.4	76.2	77.4
Aug. 15	76.7	80.8	82.7	82.4	79.8	74.7	68.2	60.9	59.2	60.1
Aug. 30	78.5	80.7	80.6	77.7	72.1	65.5	57.3	47.7	38.8	38.9
Sept. 14	79.8	79.8	77.5	72.8	65.9	58.8	46.9	34.5	21.9	14.7
Sept. 29	80.5	78.4	73.8	67.0	57.8	47.0	36.2	22.5	9.0	------
Oct. 14	80.7	76.4	69.7	61.0	50.2	38.2	25.7	12.6	1.0	------
Oct. 29	79.9	73.5	65.0	54.6	42.5	30.1	17.5	5.2	------	------
Nov. 13	78.8	70.7	60.8	49.8	37.1	23.8	11.0	0.9	------	------
Nov. 28	77.5	68.3	57.3	45.3	31.8	18.9	6.8	------	------	------
Dec. 13	76.9	66.9	55.4	43.0	30.3	16.3	4.9	------	------	------

To indicate the law of the sun's diurnal intensity to the eye also, I have taken the relative units in the table as ordinates, and their times for abscissas, and traced curves through the series of points thus determined, as shown in the accompanying diagram.


Jan.
Mar.
May
July
Sept
Nov.
Temperature
Intensity
Equator
Lat. 10°
Intensity
Lat. 10°
Temperature Calcutta
Lat. 20°
Intensity
Lat. 20°
Intensity
Temperature New Orleans
Lat. 30°
Lat. 30°
Lat. 40° Intensity
Temperature Philadelphia
Lat. 40°
Units of Intensity (Deg. Fah.)
Units of Intensity (Deg. Fah.)
Winter
Spring
Summer
Autumn
Winter

The equatorial curve will be observed to have two maxima at the equinoxes in March and September, and two minima at the solstices in June and December. Since the earth is nearer the sun in March than in September, the curve shows a greater intensity in the former month, other things being equal.

In the latitude of 10° the sun will not be vertical at the summer solstice, but only when the declination is 10° N., which happens twice in the year. The curve corresponds in every particular with the known course of the sun. Above the latitude of 23° 28′ the tropical flexure entirely disappears; and there is only a single maximum at midsummer.

For comparison with the curves of *intensity*, I have also traced curves of *temperature* observed at Calcutta, in lat. 22° 33′ N.; at New Orleans, in lat. 29° 57′; and at Philadelphia, in lat. 39° 57′. The curve for Philadelphia is adjusted from the daily observations made at the Girard College Observatory from 1840 to 1845, under the direction of Prof. Bache. The rest are interpolated graphically from the mean monthly temperatures.

Retardation of the effect.—In the temperate zone the temperatures will be seen to attain their maximum about one month later than the sun's intensity would indicate. At Stockholm it is somewhat more than a month; and, during this interval the earth must receive during the day more heat than it loses at night; and, conversely, after the winter solstice it loses more heat during the night than it receives by day. In illustration of this point, and to approximately verify the formula, I here insert a former computation of the sun's intensity for the 15th day of each month, on the latitude of Mendon, Mass., and the results are found to agree very nearly with those observed at that place about *one month later*, as follows: (The observed values are taken from the *American Almanac* for 1849, and are derived from fifteen years' observations.)

Computed values.			Observed values.		Difference.
January 15	5040	23°.3	24°.3	February 15	+1°.0
February 15	7142	33°.1	33°.5	March 15	+ .4
March 15	9764	45°.2	45°.8	April 15	+ .6
April 15	12574	58°.3	55°.0	May 15	—3°.3
May 15	14482	67°.1	64°.5	June 15	—2°.6
June 15	15346	71°.1	71°.8	July 15	+ .7
July 15	15085	69°.9	68°.9	August 15	—1°.0
August 15	13437	62°.3	61°.0	September 15	—1°.3
September 15	10860	50°.3	48°.5	October 15	—1°.8
October 15	8080	37°.5	38°.9	November 15	+1°.4
November 15	5638	26°.1	27°.7	December 15	+1°.6
December 15	4510	20°.9	26°.0	January 15	+5°.1

It may be proper to observe that the formula was divided by *sin L*, a constant factor; and the numbers in the second column were then successively computed: their sum, divided by twelve, gave 10163 as the mean, to be compared with 47°.1, the observed mean at Mendon. Then as 10163 : 47°.1 : : 5040 : 20°.3, Jan. 15, &c. Let it also be

observed, that the Mendon values are the monthly means, which do not always fall on the 15th day, but nearly at that time.

Rate per hour of the sun's intensity.—To glance at the subject from another point of view, let us consider the *rate*, or the relative number of heating rays per hour. For any day, if we divide the computed intensity by the length of the day, the quotient will express the average hourly intensity.

In the accompanying table the values of the rate are exhibited at intervals of fifteen days, and for every ten degrees of latitude. The peculiar variation of the values for latitude 70° evidently arises from the change to constant day. And apparently the hourly rates coincide more nearly with the temperatures than do the diurnal intensities or absolute amounts.

Average rate of the sun's hourly intensity, or relative number of vertical rays per hour.

A. D. 1853.	Latitude 0°.	Latitude 10°.	Latitude 20°.	Latitude 30°.	Latitude 40°.	Latitude 50°.	Latitude 60°.	Latitude 70°.	Latitude 80°.	Latitude 90°.
Jan. 1	6.43	5.89	5.16	4.24	3.26	2.08	0.88	------	------	------
Jan. 16	6.51	5.99	5.32	4.44	3.44	2.32	1.12	------	------	------
Jan. 31	6.63	6.20	5.56	4.66	3.86	2.75	1.56	0.34	------	------
Feb. 15	6.75	6.38	5.85	5.05	4.27	3.22	2.11	0.92	------	------
Mar. 2	6.80	6.59	6.11	5.50	4.71	3.78	2.70	1.56	0.35	------
Mar. 17	6.83	6.70	6.38	5.85	5.15	4.25	3.17	2.21	1.03	------
April 1	6.73	6.71	6.50	6.09	5.51	4.73	3.82	2.76	1.64	0.86
April 16	6.58	6.67	6.56	6.21	5.70	5.02	4.24	3.22	1.83	1.86
May 1	6.40	6.59	6.57	6.33	5.86	5.32	4.50	3.52	2.68	2.72
May 16	6.23	6.48	6.53	6.40	6.01	5.46	4.71	3.55	3.35	3.40
May 31	6.08	6.39	6.49	6.36	6.07	5.54	4.78	3.62	3 79	3.85
June 15	6.00	6.33	6.45	6.34	6.07	5.57	4.81	3.82	4.00	4.07
July 1	6.01	6.32	6.44	6.36	6.12	5.58	4.83	3.78	3 96	4.03
July 16	6.08	6.38	6.46	6.37	6.01	5.51	4.75	3.51	3.68	3.74
July 31	6.22	6.46	6.50	6.32	5.98	5.42	4.65	3.55	3.18	3.22
Aug. 15	6.39	6.56	6.50	6.30	5.87	5.23	4.38	3.43	2.47	2.50
Aug 30	6.54	6.60	6.48	6.12	5.53	4.87	4.05	3.10	1.90	1.62
Sept. 14	6.64	6.60	6.37	5.92	5.45	4.70	3.68	2.61	1.50	0.61
Sept. 29	6.70	6.57	6.21	5.68	4.93	4.05	3.16	2.04	0.89	------
Oct. 14	6.73	6.47	6.01	5.36	4.53	3.58	2.56	1.42	0.22	------
Oct. 29	6.66	6.29	5.74	5.00	4.08	3.09	2.00	0.80	------	------
Nov. 13	6.56	6.12	5.48	4.72	3.75	2.66	1.48	0.25	------	------
Nov. 28	6.46	5.9	5.26	4.42	3.36	2.28	1.08	------	------	------
Dec. 13	6.40	5.86	5.13	4.25	3.28	2.06	0.87	------	------	------

A close agreement, however, could not reasonably be expected; for the intensities represent the sun's effect at the summit of the atmosphere, but the temperatures at its base. Indeed, the sun's intensity

upon the exterior of the earth's atmosphere, like the fall of rain or snow, is a primary and distinct phenomenon. While passing through the atmosphere to the earth the solar rays are subject to refraction, absorption, polarization and radiation; also to the effects of evaporation of winds, clouds, and storms. Thus the heat which finally elevates the mercurial column of the thermometer is the resultant of a variety of causes, a single thread in the network of solar and terrestrial phenomena.

Indication of tropical calms.—Should the inquiry be made, in what part of the earth the sun's intensity continues most uniform for the longest period, an inspection of the flexures of the curves at once indicates the region intermediate between the equator and the tropic of Cancer on the one side, and of Capricorn on the other. Thus the curve for latitude 10° shows the solar intensity to be nearly stationary during half the year, from March to September. During October and November it falls rapidly, and after remaining nearly unchanged for a few days in December it again rises rapidly in January and February. As the sun's heat is the prime cause of winds, we might infer that this region would be comparatively calm during the half year mentioned, and that in the remaining months there would be greater atmospheric fluctuations.

Such were the general indications of the plate representing the *amounts;* and, on recurring to the table representing the *rates* of diurnal intensity, the status is precisely similar, except that the region of summer calm is removed further from the equator and nearer to the tropic. On referring to a recent work on the physical geography of the sea, with respect to this circumstance, I find that "the variables," or calms of Cancer and of Capricorn, occur in the very latitudes thus indicated by the compound effect of the amount and rate of solar intensity. And, further, the annual range of solar intensity, which is least upon the equator, has its counterpart in the belt of equatorial calms, or "doldrums." The same effect extends also to the ocean itself, and appears in the tranquillity of the Sargosso sea. While the curves of intensity for the higher latitudes are significant hieroglyphs of the serenity of summer, and the more violent winds and storms of March and September. The entire deprivation of the sun's intensity during a part of the year within the Arctic and Antarctic circles may also produce a polar calm, at least during the depth of winter. But the existence of such calm, though probable, can neither be disproved nor verified, as the pole appears not to have been approached nearer than within about five hundred miles. Parry and Barrow believed that a perfect calm exists at the pole.

SECTION V.

THE SUN'S ANNUAL INTENSITY UPON ANY LATITUDE OF THE EARTH.

By the method explained in the last section, the diurnal intensity, in a vertical direction, might be computed for each and every day in the year, and the sum total would evidently represent the annual intensity.

The sum of the daily intensities for a month, or monthly intensities, might be found in the same manner. But, instead of this slow process, we first find an analytic expression for the aggregate intensity during any assigned portion of the year, and then for the whole year. The summation is effected by an admirable theorem, first given by Euler; a new investigation of which, with full examples by the writer, may be found in the *Astronomical Journal*, (Cambridge, Mass.,) Vol. 2, and in the Smithsonian memoir. By this general summation the following remarkable principle was rigorously demonstrated:

The sun's annual intensity upon any latitude of the earth is proportional to the sum of two elliptic circumferences of the first and the second order, diminished by an elliptic circumference of the third order.

On the equator, the sun's annual intensity reduces to the circumference of an ellipse, whose ratio of eccentricity is equal to the sine of the obliquity of the ecliptic.

In the frigid zones, where the regular interchange of day and night in every twenty-four hours is interrupted, the formula will require modification, though the general enunciation of the elliptic functions remains the same. The year in the polar regions is naturally divided into four intervals, the first of which is the duration of constant night at mid-winter. The second interval at mid-summer is constant day; the third and fourth are intermediate spring and autumnal intervals, when the sun rises and sets in every twenty-four hours.

With respect to the unit of measure for annual intensity, the mean tropical year contains 365.24 days; let this represent the annual number of vertical rays impinging on the equator; that is, *let the sun's intensity during a mean equatorial day be taken as the thermal day*, and let the values for all the latitudes be converted in that proportion.* Also denoting the annual intensity on the equator by 12, the mean equatorial *month* may be used as another thermal unit. And taking the annual intensity on the equator as 81.5 *units*, with reference to Brewster's formula, the intensity on other latitudes may be expressed in that proportion. It may here be observed that the diurnal value of the last section will be changed to this scale by increasing them in the ratio of 1 to 1.049.

With the aid of Legendre's elliptical tables the computation of annual intensities is entirely practicable. The results converted into units, with differences for every five degrees of latitude, have been carefully verified and tabulated as follows:

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* The three species of circumferences, each representing four equal and similar quadrants, are discussed at great length by Legendre in his *Traité des Fonctions Elliptiques*. Let L denote the latitude of the place, and developing in thermal days for the torrid and temperate zones, we find for any year in the present century:

$$\text{Annual intensity} = 349.322 \cos. L + \frac{15.748}{\cos. L} + \frac{0.1628}{\cos.^3 L} + \frac{0.0066}{\cos.^5 L} + \text{----}$$

The sun's annual intensity.

Latitude.	Thermal units	Thermal months.	Thermal days.	Diff. days.	Latitude.	Thermal units.	Thermal months.	Thermal days.	Diff. days.
0°	81.50	12.00	365.24	1.27	50°	55.73	8.21	249.74	20.92
5	81.22	11.96	363.97	3.78	55	51.06	7.52	228.82	21.06
10	80.38	11.83	360.19	6.28	60	46.36	6.83	207.76	19.91
15	78.97	11.63	353.91	8.70	65	41.92	6.17	187.85	14.81
20	77.03	11.34	345.21	11.01	70	38.61	5.69	173.04	9.82
25	74.57	10.98	334.20	13.20	75	36.42	5.36	163.22	6.59
30	71.63	10.55	321.00	15.30	80	34.95	5.15	156.63	3.80
35	68.21	10.04	305.70	17.15	85	34.10	5.02	152.83	1.24
40	64.39	9.48	288.55	18.76	90	33.83	4.98	151.59	0.00
45	60.20	8.86	269.79	20.05					

From this table it will be seen that, at the tropic of Capricorn, or of Cancer, the sun's annual intensity is but eleven thermal months, being twelve on the equator. In the latitude of New Orleans the annual intensity in a vertical direction is ten and a half thermal months, and in the latitude of Philadelphia nine and a half. At London the annual intensity is reduced to eight thermal months; and at the polar circle to six months, being just one-half the value on the equator. Thus the intensity irregularly decreases till it terminates at the South or North Pole, where the annual intensity is but five thermal months.

Again, it will be interesting to note the analogy which the differences for every five degrees of latitude, in the last column of the table, bear to the corresponding differences of *height in the atmosphere which limit the region of perpetual snow.* It has been observed that the different heights of perpetual frost "decrease very slowly as we recede from the equator until we reach the limits of the torrid zone, when they decrease much more rapidly The average difference for every five degrees of latitude in the temperate zone is 1.318 feet, while from the equator to 30° the average is only 664 feet, and from 60° to 80° it is only 891 feet—important meteorological phenomena depend on this fact.—(*Olmsted's Natural Philosophy.*) The differences of computed annual intensity in the table vary in a manner precisely similar. While, in the temperate zone, the decrease for every five degrees of latitude is from 13 to 21 thermal days, yet it averages only about 6 thermal days within the tropics and beyond the polar circles. The line of congelation evidently rises in summer and falls in winter between certain limits.

With reference to the connexion between these annual intensities and the observed annual temperatures, the analogy of the centigrade scale shows that units of intensity may be converted into degrees Fahrenheit by a multiplier and constants. Since the values of the multiplier and constants are not precisely known, a graphical construction will be employed; and it is plain that if computed intensities and observed temperatures both follow the same law of change, their delineated curves will be symmetrical.

Therefore, taking the latitudes for ordinates, and the annual intensities in the table for abscissas, we obtain the curve of annual intensity; and, in the same manner, the curve of annual temperature. It will be seen, no doubt with interest, that the curve of annual intensity is almost symmetrical with that of European temperature, observed mostly on the western side of that continent. But the curve of American temperature based on the United States army observations for places on the eastern portion of the continent, diverges from the curve of intensity, and indicates a special cause depressing these temperatures below the normal standard due to their latitudes.

At Key West, on the southern border of Florida, the divergence commences, and on proceeding northwardly continually increases in magnitude; that is, so far as reliable observations have been made along the expanding breadth of the North American continent.

It were natural to suppose that the annual temperature would be defined by the annual number of heating rays from the sun. Indeed on and near the tropical regions, the curves of annual temperature and solar intensity are symmetrical. But in the polar regions, the irregularity of the intervals of day and night, and of the seasons, and various proximate causes, introduce a discrepancy, which the principle of annual average does not obviate. The laws of solar intensity, however, have been determined; the laws of climatic temperature will require a special and apparently more difficult analysis.

It has been inferred that there are two poles of maximum cold about the latitude of 80° north, and in longitudes 95° E. and 100° W. The fewness of the observations, however, in that remote hyperborean region, leaves this question still open to investigation.

SECTION VI.

AVERAGE ANNUAL INTENSITY OF THE SUN UPON A PART OR THE WHOLE OF THE EARTH'S SURFACE.

Having determined the sun's vertical intensity upon a single unit or point of the earth's surface, let us next ascertain the average annual intensity upon a larger area, a zone, or the entire surface of the globe. After which, we shall glance at some of the climatic alternations which are most clearly made known and interpreted by the mechanism of the heavens.

In any zone of the earth the sum of the annual intensities divided by the surface will evidently give the mean annual intensity upon the unit of surface. On this principle the following results were derived, but the analytic process is here omitted:

The sun's average annual intensity.

	Thermal days.	Thermal months.	Thermal units.
Upon the polar zones	166.04	5.45	37.05
Upon the temperate zones	276.38	9.08	61.67
Upon the torrid zone	356.24	11.70	79.49
Upon the whole earth	299.05	9.83	66.73

Thus it appears that the sun's annual intensity upon the whole earth's surface from pole to pole averages 299 thermal days, being five sixths of the value on the equator.

Though the figures in the last column are strictly units of *intensity*, yet, as shown by the curves, they also approximately represent annual *temperatures*, except near the poles. Following these indications, the mean annual temperature of the whole earth's surface must be somewhat below 66° Fahrenheit. In comparison with this result, the mean annual temperature found by Professor Dove, from a vast number of observations, may be introduced, which is approximately 58°.1 Fahrenheit. The like value found from the formula of Brewster, is 64°.0 Fahrenheit.

SECTION VII.

ON SECULAR CHANGES OF THE SUN'S INTENSITY.

In relation to secular variations of intensity, we shall adopt the hypothesis that the physical constitution of the sun has remained constant. The secular changes here considered, therefore, are those which depend solely on position and inclination, according to the laws of physical astronomy.

The recurrence of spots on the sun's disc has lately been discovered to observe a regular periodicity. But their influence upon temperature appears to be insufficient for taking account of them. M. R. Wolf, in the *Comptes Rendus*, XXXV, p. 704, communicates his discovery that the minima of solar spots occur in regular periods of 11.111 years, or nine cycles in a century—and that the years in which the spots are most numerous are generally drier and more productive than the others—the latter being more humid and showery. Counsellor Schwabe, after twenty-six years of observation, does not think that the spots exert any influence on the annual temperature. And a writer in the *Encyclopædia Britannica*, article Astronomy, states that "in 1823 the summer was cold and wet, the thermometer at Paris rose only to 23°.7 of Reaumur, and the sun exhibited no spots; whereas, in the summer of 1807 the heat was excessive, and the spots of vast magnitude. Warm summers and winters of excessive rigor have happened in the presence or absence of the spots."*

Proceeding now to investigation, our first inquiry will relate to *changes of the sun's annual intensity upon the earth's surface regarded as one aggregate.*

In the *Connaissance des Tems*, for 1843, Leverrier has exhibited the secular values of most of the elements of the planetary orbits during 100,000 years before and after January 1, 1800. The eccentricity of the earth's orbit at the present time being .0168, the value 100,000 years ago, and the greatest in that interval was .0473. Substituting these in the formula, we find that the sun's annual intensity

* Professor Henry was the first to show, by projecting on a screen in a dark room the image of the sun from a telescope with the eye glass drawn out, that the temperature of the spots was slightly less than that of the other parts of the solar disc. The temperature was indicated by a delicate thermoelectrical apparatus. Professor Secchi, of Italy, afterwards obtained the same result.—See *Silliman's Journal*, Vol. XLIX, p. 405.

at the former epoch was greater than at present by one-thousandth part. Now this fraction of 365.24 days, counting the days at twelve hours each in respect to solar illumination, amounts to *between four and five hours of sunshine in a year;* and by so small a quantity only has the sun's annual intensity, during 100,000 years past, ever exceeded the yearly value at the present time. Nor can it depart from its present annual value by more than the equivalent of five hours of average sunshine in a year for 100,000 years to come.

The superior and *ultimate limit* given by Leverrier, to which the eccentricity of the earth's orbit may have approached at some very remote but unknown period or periods, is .0777. At such epoch, the annual intensity is computed, as before, to have exceeded the intensity of the present by *thirteen hours* of sunshine in a year. On the other hand, the inferior limit of eccentricity being near to zero, indicates only *four minutes* of average sunshine in a year, less than the present annual amount. Between these two extreme limits, all annual variations of the solar intensity, whether past or future, must be included, even from the primitive antediluvian era, when the sun was placed in his present relation to the earth. By the third law of Kepler, on which the equation is based, these results are rigorous for siderial years; and by reason of the slight but nearly constant excess, the same may be concluded of tropical or civil years. For the annual variation of the tropical year is only—0d.00000006686.

The preceding conclusions, it is proper again to observe, refer to the whole earth's surface collectively. Let us, in the next place, inquire concerning *changes of annual intensity upon the different latitudes* of the earth. This variation will be a function of the eccentricity, and the obliquity. For the present, let it be proposed to compute the annual intensity for an epoch 10,000 years prior to A. D. 1800. The eccentricity of the orbit, was then .0187, according to Leverrier; and for the obliquity of the ecliptic, the most correct formula is probably that of Struve and Peters, quoted in the *American Nautical Almanac*. It is true their formula may not strictly apply for so distant a period; but, since the value 24° 43′ falls within the maximum assigned by Laplace, it must be a compatible value, though its epoch may be somewhat nearer or more remote than 10,000 years. Therefore, comparing the computed results with the table for 1850, given in Section V, as a standard, we find the annual intensity on the equator, at the former period, to have been 1.65 thermal days less than in 1850; the differences for every ten degrees of latitude are as follows:

Change of the sun's annual intensity 8,200 *years B. C., from its value in A. D.* 1850, *taken as the standard.*

Latitude.	Difference in thermal days.	Latitude.	Difference in thermal days.	Latitude.	Difference in thermal days.
0°	—1.65	40°	—0.22	70°	+5.52
10°	—1.58	50°	+ .68	80°	+7.18
20°	—1.32	60°	+2.11	90°	+7.64
30°	— .96				

From this it appears that the annual intensity within the Torrid Zone, ten thousand years ago, averaged one thermal day and a half less than now; while from 35° of latitude to 50°, comprehending the whole area of the United States, it was virtually the same as at the present day. But above 50° of latitude, the annual intensity was then greater in an increasing rate towards the pole, at which point it was between seven and eight thermal days greater than at the present time; in other words, the poles both north and south, 10,000 years ago, received twenty rays of solar heat in a year, where they now receive but nineteen. Owing to change in the obliquity of the ecliptic, the sun may be compared to a swinging lamp; at the former period, it apparently moved farther to the north and to the south, passing more rapidly over the intermediate space.

The maximum variation of the obliquity of the ecliptic, according to Laplace, without assigning its epoch, is 1° 22′ 34″, above or below the obliquity 23° 28′ in the year 1801.* Now the difference recognized in our calculation almost reaches this limit, being 1° 15′. As the secular perturbations are now understood, therefore, it follows that, since the earth and sun were placed in their present relation to each other, the annual intensity upon the Temperate Zones has never varied; between the tropics, it has never departed from its present annual amount by more than about $\frac{1}{240}$th part, and is now very slightly increasing. The most perceptible difference is in the Polar regions, where the secular change of annual intensity is more than four times greater than on the Equator; in its annual amount, the Polar cold is now very slowly increasing from century to century, which effect must continue so long as the obliquity of the ecliptic is diminishing. And thus, so far as relates to a decreased annual intensity, the celebrated "Northwest passage" through the Arctic sea will be even more difficult in years to come than in the present age.

Having now considered the secular changes of annual intensity upon the earth and its different latitudes, let us next examine the *secular changes of intensity in relation to the Northern and Southern hemispheres.* The earth is now nearest the sun in winter of the northern hemisphere on January 1st, and farthest from the sun in summer on July 4th. This collocation of times and distances has the advantage of rendering the extreme of summer cooler, and of winter, north of the equator, warmer than it would be at a mean distance from the sun. But south of the equator, on the contrary, it exaggerates the extremes by rendering the summer hotter and the winter colder. Before estimating this difference, we may observe that the perigee advances in longitude 11″.8 annually; by which the instant when the earth is nearest the sun, will date about five minutes in time later every year. The time of perihelion, which now falls in January, will at length occur in February, and ultimately return to the southern hemisphere the advantage which we now possess. Indeed, it is remarkable that the perigee must have coincided with the autumnal equinox about 4,000 B. C., which is near the time that chronology assigns for the first residence of man upon the earth.

* Mécanique Céleste, Vol. II, p. 856, note, Bowditch's translation.

For ascertaining the difference of intensity, we know that the sun's declination goes through a nearly regular cycle of values in a year. The formula shows that the length of the day in the southern hemisphere is the same as in the northern hemisphere about six months earlier. The ratio of daily intensity of the northern, is to the southern then as 1 to $1-\frac{1}{15}$. And the like ratio for the summer intensities is as 1 to $1+\frac{1}{15}$. But $\frac{1}{15}$ is the extreme deviation for a few days only; the mean between this and 0, or $\frac{1}{30}$, would seem more correctly to apply to the whole seasons of summer and winter. Taking then $\frac{1}{30}$th of the greatest and least values of daily intensity, Section IV, for the temperate zone, it appears that winter in the southern hemisphere is now about 1° colder, and summer 3° hotter than in the northern hemisphere. The intensities during spring and autumn may be regarded as equal in both hemispheres. And the summer season of the south temperate zone being hotter, is also shorter by about eight days, owing to the rapid motion of the earth about the perihelion.

In confirmation of these last deductions, the younger Herschel refers to the glow and ardor of the sun's rays under a perfectly clear sky at noon, and observes, "one-fifteenth is too considerable a fraction of the whole intensity of sunshine, not to aggravate, in a serious degree, the sufferings of those who are exposed to it without shelter. The accounts of these sufferings in the interior of Australia, would seem far to exceed what have ever been experienced by travellers in the northern deserts of Africa. The author has observed the temperature of the surface soil in South Africa, as high as 159° Fahrenheit. The ground in Australia, according to Captain Sturt, was almost a molten surface, and if a match accidently fell upon it, it immediately ignited." (*Herschel's Astronomy.*)

The phenomenon is of sufficient interest to warrant a glance at the secular values. The eccentricity, 100,000 years ago, has already been stated at .0473; and the formula of the proportional general difference of the winter intensities, in the northern and southern hemispheres, becomes 1 — .0946; and the maximum difference becomes 1 — .1892. Thus the difference of winter intensities between the northern and southern hemispheres, and likewise of summer intensities, was then about three times greater than at the present time. But this wide fluctuation of summer and winter intensities, in relation to the two hemispheres, scarcely affected the aggregate *annual* intensities, as before shown.

From occasional *Historic notices of climate*, it has been assumed that the winter season in Europe was formerly colder than at the present time. The rivers Rhine and Rhone were frozen so deep as to sustain loaded wagons; the Tiber was frozen over, and snow at one time lay forty days in the city of Rome; but the history of the weather presents winters of equal severity in modern times. Thus, in the famous winter of 1709, thousands of families perished in their houses; the Arabic Sea was frozen over, and even the Mediterranean. The winter of 1740 was scarcely inferior, and snow lay ten feet deep in Spain and Portugal. In 1776 the Danube bore ice five feet deep below Vienna. In the United States, likewise, since the period of our colonial history, the indications of an amelioration of climate are not conclusive. The

great snow of February, 1717, rose above the lower doors of dwellings, and in the winters which closed the years 1641, 1697, 1740, and 1779, the rivers were frozen, and Boston and Chesapeake bays were at times covered with ice as far as the eye could reach; but the like occurs at similar intervals in our day. Mild winters, too, have intervened, and the other seasons are also very variable. The general indications, however, give rise to the question, whether there is a cause of change of climate in the course of the sun?

About two thousand years ago, in the time of Hipparchus, 128 B. C., the obliquity of the ecliptic, or the sun's greatest declination, was $23° 43'$. It has now decreased to $23° 27\frac{1}{2}'$; therefore, at the former epoch, the sun came farther north and rose to a higher altitude in summer; and went farther south and rose only to a lower altitude in midwinter. There is then an astronomic cause of change, of which we propose to determine more precisely the effect.

Let the latitude be 40°, which is nearly the latitude of Philadelphia, also of southern Italy and Greece. Computing now for B. C. 128, and for A. D. 1850, the daily intensities at the summer solstice are 90.45 and 90.05 thermal units, and at the winter solstice 28.67 and 29.04 respectively. The differences .40 and .37 must correspond almost precisely to degrees of the thermometer; and halving them for the whole seasons, as before described, we are conducted to the following conclusion. In the time of Hipparchus, or about a century before Julius Cesar, Virgil, Horace and Ovid flourished, *under the latitude of Italy and Greece the summer was two-tenths of a degree Fahrenheit hotter, and the winter as much colder, than at the present day.* The similar changes of solar intensity upon the United States in two hundred years, can only be made known by theory, and are evidently very slight. There has been, therefore, no sensible amelioration of climate in Europe or America from astronomical causes. The effects, however, of cutting down dense forests, of the drainage and cultivation of open grounds and woodlands admit of conflicting interpretation, and appear but secondary to the atmospheric fluctuations which are governed by the changes in the relative position of the earth and sun.

Before leaving the subject, the inquiry may arise respecting *Geological changes*, whether the secular inequalities have ever been of such value under the present order, as to admit of tropical plants growing in the temperate or frigid zones. In reply, as the annual intensity could never have varied in any considerable degree, the change must consist entirely in tempering the extremes of summer and winter to a perpetual spring. And this could not happen on both sides of the equator at once; for the same astronomic arrangement which made the daily intensities in the northern hemisphere equable, would subject those of the southern to violent alternations; and the wide breadth of the torrid zone would prevent the effects being conducted from one hemisphere to the other.

Let us then look back to that primeval epoch when the earth was in aphelion at midsummer, and the eccentricity at its maximum value—assigned by Leverrier near to .0777. Without entering into elaborate computation, it is easy to see that the extreme values of

diurnal intensity, in Section IV, would be altered as by the multiplier $1 - 0.11$ in summer, and $1 + 0.11$ in winter. This would diminish the midsummer intensity by about 9°, and increase the midwinter intensity by 3° or 4°; the temperature of spring and autumn being nearly unchanged. But this does not appear to be of itself adequate to the geological effects in question.

It is not our purpose here, to enter into the inquiry, whether the atmosphere was once more dense than now, whether the earth's axis had once a different inclination to the orbit, or the sun a greater emissive power of heat and light. Neither shall we attempt to speculate upon the primitive heat of the earth nor of planetary space, nor of the supposed connection of terrestrial heat and magnetism; nor inquire how far the existence of coal fields in this latitude, of fossils, and other geological remains have depended upon existing causes. The preceding discussion seems to prove simply that, under the present system of physical astronomy, the sun's intensity could never have been very greatly different from what is manifested upon the earth at the present day. *The causes of notable geological changes must be other than the relative position of the sun and earth, under their present laws of motion.*

If we extend our view, however, to the general movement of the Sun and Planets in space, we find here a *possible* cause for the remarkable changes of temperature traced in the geological periods. For, as Poisson conjectured, *Théorie de la Chaleur*, p. 438, the phenomena may depend upon an inequality of temperature in the regions of space, through which the earth has passed. According to a calculation quoted by Prof. Nichol, the velocity of this great movement is six times greater than that of the earth in its orbit, or about 400,000 miles per hour.

In this motion, continued for countless ages, the earth may have traversed the vicinity of some one of the fixed stars, which are suns, whose radiance would tend to efface the vicissitudes of summer and winter, if not of day and night, with a more warm and equable climate. This may have produced those luxuriant forests, of which the present coal fields are the remains; and thus the existence of coal mines in Disco, and other Arctic islands, may be accounted for. If no similar traces exist in the Antarctic zone, the presumption will be strengthened, that the North Pole was presented more directly to the rays of such illuminating sun or star. Indeed, by this position, all possibility of conflict with Neptune, and the other planets which lie nearly in the plane of the ecliptic, were avoided.

The description of such period, with strange constellations and another sun gleaming in the firmament, their mysterious effects upon the growth of animals and vegetation, their untold vicissitudes of light, shadow and eclipse, belong to the romance of astronomy and geology. As in the ancient tradition described by Virgil in the sixth Eclogue:—

> Jamque novum terræ stupeant lucescere solem:
> Altiūs atque cadant submotis nubibus imbres:
> Incipiant silvæ quam primūm surgere, quumque
> Rara per ignotos errent animalia montes.

It is evident that, in receding from the sphere of intensity of such star, as a comet from the sun, the earth's annual temperature would very slowly decrease in process of time, according to the temperature of the space traversed. And, at a remote distance from the stars, the temperature of space ought to remain stationary; as the mean annual temperature of the earth has remained for at least two thousand years past, and without doubt will so continue for ages to come.

Section VIII.

ON LOCAL AND CLIMATIC CHANGES OF THE SUN'S INTENSITY.

As the principal topics under this head have been anticipated in the former portions of the work, they need not here be repeated. The inequality of winter, and especially of summer intensities in the northern and southern hemispheres, has already been discussed in the last Section, and ascribed to the changing position of the sun's perigee.

Let us now pass to another local inequality, which consists in the difference of daily intensities at two places situated on the same parallel of latitude, but separated by a considerable interval of longitude. This difference arises solely from hourly change of the Sun's Declination, while moving from the meridian of one place westward to the meridian of the other; the Sun in the interval attaining a higher or lower meridian altitude.

For example, the latitude of Greenwich, near London, is 51° 28′ 39″. Following this parallel west to a point directly north of San Francisco, in California, the difference of longitude is 122° 28′ 2″. At the time of the autumnal equinox, the daily change of the sun's declination is 23′ 23″. Consequently, in passing from the meridian of Greenwich to that of San Francisco, the declination is diminished by 7′ 57″.3.

When the Sun's Declination is 0, at apparent noon at Greenwich, on Sept. 21st, it will be 7′ 57″.3 S. at noon in the longitude of San Francisco, on the same day; the semi-diameter being 15′ 59″ or 959″ for Greenwich, and 959″.1 for San Francisco. With these elements, let the sun's daily intensity be computed for both places. The result is 50.13 thermal units for Greenwich, and 49.91 for the place north of San Francisco, on the same latitude. The difference is .22 corresponding to nearly + $\frac{1}{4}$° Farenheit; and by so much the intensity upon the zenith of Greenwich is greater, on the same day.

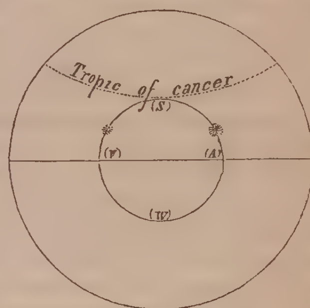
At the vernal equinox, March 20, the sun's daily change of declination would be in the opposite direction, and the difference would become—$\frac{1}{4}$°F. The inequality of this species thus compensates itself in theory, leaving the *yearly* intensity the same for all places having the same latitude.

For further reference on this point, the daily changes of declination, near the first of each month, are subjoined as follows:—

January,	5′	May,	18′	September,	22′
February,	18′	June,	8′	October,	23′
March,	23′	July,	5′	November,	18′
April,	23′	August,	17′	December,	9′

In this connection, it may be observed that Nervander, Buys Ballot, and Dove have developed a slight inequality of temperature dependent upon the Sun's rotation around his axis, and having the same period of about 27 days; but this result is not confirmed by Lamont, *Poggendorff's Annalen* for 1852.

With respect to maxima and minima, the foregoing Plate exhibits a resemblance to two summers and to two winters on the Equator—the sun being vertical at the two equinoxes. On receding from the equator, but still in the torrid zone, the sun will be vertical at equal intervals, before and after the summer solstice, which intervals diminish as the sun approaches the Tropic; the sun being vertical to each locality, when his declination is equal to the latitude of the place; as indicated in the annexed diagram.



On arriving at the Tropic in the yearly motion, the sun can be vertical but once in the year, namely, at the summer solstice. At all places more distant from the equator the sun can never be vertical, but will approach nearest this position at the solstice in summer (*s*), and be farthest from it at the solstice of winter (*w*). Thus in the torrid zone, the sun's daily intensity has two maxima and two minima annually; in the temperate zones, one maximum and one minimum; and in the frigid zones, one maximum.

Owing to change of the sun's distance, the intensity is not precisely the same at the autumnal equinox as at the vernal; the difference, however, being small, may here be neglected. And for more full illustration, a horizontal projection might be drawn of the Table in Section IV, showing the Sun's Diurnal Intensity along the meridian at intervals of thirty days, from June to December, and approximately for the other months. The alternate curves will of course show the sun's changes of intensity in intervals of sixty days.

It will be seen that the sun's least yearly range of intensity is not on the Equator, but about 3° of latitude from it north and south. Here the daily heat is most constant, and perpetual summer reigns through the year.

In like manner, the diverging curves show an increasing yearly range, which is greatest in the Polar regions. Also the changes from one day to another are most rapid in spring and autumn. The greatest intensity occurs at the summer solstice, June 21, and the least, at the winter solstice, December 21; so that the yearly range from minimum to maximum is a little wider than the drawn curves indicate. Near the Polar Circle, a singular inflection commences in summer, and the temperature rises rapidly to the Pole.

These laws of Intensity are subject to the retardation in time, mentioned in Section IV, when applied to temperatures, and thus will correspond, generally, with observations. For example, the

thermometric column will, during the month of May, rise faster at Quebec than in Florida, and still more rapidly at the Arctic Circle.

It was proved, in Section IV, that the Sun's intensity upon the Pole during eighty-five days in summer, is greater than upon the Equator. Indeed, at the summer solstice it rises to 98.6 thermal units, corresponding nearly to 98° Fahrenheit, which singularly coincides with the temperature of the human body, or blood heat.

Though this circumstance may invest the Hyperborean region with new interest, still we cannot assume a brief tropical summer with teeming forms of vegetable and animal life in the centre of the frozen zone. For the measured intensity refers to the outer limit of the atmosphere, upon which the sun shines continually, but from a low altitude which cannot exceed 23° 28′. Much of the heat must, therefore, be absorbed by the air, as happens near the hours of sunrise and sunset in our climate. Also "the vast beds of snow and fields of ice, which cover the land and the sea in those dreary regions, absorb, in the act of thawing or passing to the liquid form, all the surplus heat collected during the continuance of a nightless summer. But the rigor of winter, when darkness resumes her tedious reign, is likewise mitigated by the warmth evolved as congelation spreads over the watery surface." (*Encyc. Brit.*, article Climate.)

The sun's intensity may yet have a somewhat greater effect upon the pole where it pierces a thinner stratum of the atmosphere than over another portion of the earth's surface. For, in consequence of the centrifugal force of the earth's diurnal motion, the particles of air in all other parts of the earth, being thrown outwards, tend to an increased thickness in spheroidal strata. We might thence infer that a less proportion of the sun's rays would be absorbed, and a greater portion transmitted through the atmosphere to the surface of the earth. However this may be in the immediate vicinity of the Pole, yet in the high latitudes hitherto visited by navigators, and which are not nearer than about five or six hundred miles from the North Pole, according to Dr. Kane and others, a dense and lasting fog prevails after the middle of June, through the rest of the summer season, and effectually prevents the rise of temperature which the sun's intensity would otherwise produce.

"The general obscurity of the atmosphere arising from clouds or fogs is such, that the sun is frequently invisible during several successive days. At such times, when the sun is near the northern tropic, there is scarcely any sensible quantity of light from noon to midnight." (*Scoresby's Arctic Regions*, Vol. I, p. 378.) "The hoar-frost settles profusely in fantastic clusters on every prominence. The whole surface of the sea steams like a lime-kiln, an appearance called the *frost smoke*, caused, as in other instances of the production of vapors, by the waters being still relatively warmer than the incumbent air. At length the dispersion of the mist, and the consequent clearness of the atmosphere, announce that the upper stratum of the sea itself has become cooled to the same standard; a sheet of ice quickly spreads, and often gains the thickness of an inch in a single night."

The question of an *open unfrozen sea* in the vicinity of the North Pole has long been agitated. In this connection we shall only glance

at some of the evidences on both sides, without discussing further a subject from which the veil of uncertainty is not yet entirely removed.

"Of this I conceive we may be assured," says Scoresby, Vol. I, p. 46, "that the opinion of an open sea around the Pole is altogether chimerical. We must allow, indeed, that when the atmosphere is free from clouds, the influence of the sun, notwithstanding its obliquity, is, on the surface of the earth or sea, about the time of the summer solstice, greater at the Pole, by nearly one-fourth part, than at the equator. (See Section IV. The value was first determined by Halley, *Phil. Trans.*, 1693.) Hence it is urged that this extraordinary power of the sun destroys all the ice generated in the winter season, and renders the temperature of the Pole warmer and more congenial to the feelings than it is in some places lying near the equator. Now, it must be allowed, from the same principle, that the influence in the parallel of 78°, where it is computed in the same way to be only about one forty-fifth part less than what it is at the Pole, must also be considerably greater than at the equator. But, from twelve years' observations on the temperature of the icy regions, I have determined the mean annual temperature in latitude 78° to be 16° or 17° F., [that is about fifteen degrees below freezing point]; how, then, can the temperature of the Pole be expected to be so very different?"

After some further argument, the author remarks in a note: "Should there be land near the pole, portions of open water, or perhaps even considerable seas might be produced by the action of the current sweeping away the ice from one side almost as fast as it could be formed. But the existence of land only, I imagine, can encourage an expectation of any of the sea northward of Spitzbergen being annually free from ice."

On the other hand, the following indications in favor of an open sea, are derived from a recent article upon Arctic Researches, announcing that "the existence of the long suspected unfrozen Polar Sea has been all-but proved."

First, it was found that the average annual temperature about the 80th parallel, was higher by several degrees, than that recorded farther south. At the island of Spitzbergen, for example, under the 80th parallel, the deer propagate, and on the northern coast the sea is quite open for a considerable time every year. But at Nova Zembla, five degrees further south, the sea is locked in perpetual ice, and the deer are rarely, if ever seen on its coast. This has led physical geographers to suppose that the milder temperature of Spitzbergen must be attributable to the well known influence of proximity to a large body of water; while the contiguity of Nova Zembla to the continent was thought to account for the severity of its climate.

Secondly, Captain Parry reached Spitzbergen in May, 1827; from thence he went northward two hundred and ninety-two miles in thirty-five days, during which it rained almost all the time. The ice being much broken, and the current setting toward the south, he could not make way against it, and was compelled to return, which the current greatly facilitated. Besides the current here noticed by Parry, others had been determined before, and more have been ascertained since;

so that powerful currents of the Arctic Ocean southward, may be considered as established.

Thirdly, in 1852, Captain Inglefield, while making his summer search for Sir John Franklin, in the northeast of Baffin's Bay, beheld with surprise "two wide openings to the eastward into *a clear and unincumbered sea*, with a distinct and unbroken horizon, which, beautifully defined by the rays of the sun, showed no signs of land, save one island." Further on he remarks, "the changed appearance of the land to the northward of Cape Alexander was very remarkable. South of this cape, nothing but snow-capped hills and cliffs met the eye; but to the northward an agreeable change seemed to have been worked by an invisible agency—here the rocks were of their natural black or reddish-brown color; and the snow which had clad with heavy flakes the more southern shore had only partially dappled them in this higher region, while the western shore was gilt with a belt of ice twelve miles broad, and clad with perpetual snows."

To these may be added the discovery of the southern boundary of an open polar sea, in the expedition from which Dr. Kane has just returned, October, 1855. "There are facts," observes this distinguished explorer, "to show the necessity and certainty of a vast inland sea at the North. There must be some vast receptacle for the drainage of the polar regions and the great Siberian rivers. To prove that water must actually exist, we have only to observe the icebergs. These floating masses cannot be formed without *terra firma*, and it is a remarkable fact that, out of 360°, in only 30° are icebergs to be found, showing that land cannot exist in a considerable portion of the country. Again, Baffin's Bay was long thought to be a close bay, but it is now known to be connected with the Artic sea. Within the bay, and covering an area of ninety-thousand square miles, there is an open sea from June to October. We find here a vacant space with water at 40° temperature—eight degrees higher than freezing point."

The last narrative of Dr. Kane has since been published, in which the view is described of the open Polar sea in the month of June, and the opinion is advanced that its higher temperature arises from a continuation of the Gulf stream to that most remote locality. More recently, the observations of Commodore Rogers, in the United States ship Vincennes, who passed through Behring's Straits in the summer of 1855; "and his observations show uniformly this arrangement or stratification in the fluid mass of the Arctic ocean—warm and light water on top, cold water in the middle, and warm and heavy water at the bottom. This substratum of heavy water was probably within the tropics, and at the surface when it received its warmth. Water, we know, is transported to great distances by the under currents of the sea without changing its temperature but a few degrees on the way. Beneath the Gulf stream, near the Tropic of Cancer, with the surface of the ocean above 80°, the deep-sea thermometer of the Coast Survey reports a current of cold water only 3° above the freezing point. We know of numerous currents flowing out of the Polar basin and discharging immense volumes of water into the Atlantic; we know of but one surface current, and that a feeble one, around the North Cape, that goes into this basin. Hence, we should conclude that there must

be one or more under-currents of salt and heavy water flowing into the Arctic basin. A considerable body of water at the temperature of 40° rising to the surface there—as come to the surface it must, in order to supply the out-going upper currents—would tend mightily to mitigate the severe cold of these hyperborean regions."

SECTION IX.

ON THE DIURNAL AND ANNUAL DURATION OF SUNLIGHT AND TWILIGHT.

Having thus far considered the intensity of solar radiation upon any part of the earth, we shall lastly pass to examine its duration.

In several publications it has been stated that "the sun is, in the course of the year, the same length of time above the horizon at all places." On applying an accurate analysis, however, it appears, as will presently be shown, that the annual duration of sunlight is subject to a very considerable inequality. This annual inequality increases with the distance from the equator, and is proportional to the sine of the longitude of the sun's perigee.

The longitude of the perigee on January 1, 1850, was 280° 21′ 25″, and increasing at the rate of 61″.47 annually; the sine of the longitude of the perigee is therefore decreasing in value every year, and with it, the inequality of sunlight. At the present time it amounts, in the latitude of 60°, to 36 hours—being additive in the northern, and subtractive in the southern hemisphere. That is, in the latitude of 60° north, the total duration of sunlight in a year is 36 hours more, and in the latitude of 60° south, 36 hours less than on the equator. At either pole the inequality amounts to 92 hours, or more than seven and a half average days of twelve hours each.

Were the earth's orbit a perfect circle, the inequality could not exist; its physical cause lies in the unequal motion of the earth in its elliptical orbit. During summer of the northern hemisphere, the earth is in and near aphelion, its longitude, and consequently the declination on which the length of day depends, changes most slowly from one day to another; whereas, during summer of the southern hemisphere, it changes the most rapidly, and the longest days are fewer in number.

The epoch when the annual inequality was at its last maximum, is found by dividing the present excess of the longitude of the perigee above three right angles, by the yearly change. The excess, in 1850, was 10° 21′ 25″, which divided by 61″.47 gives a quotient of 606.5 years; which refers back to the period of the middle ages, A. D. 1243.

At a still earlier epoch, this inequality must have entirely vanished. At that epoch, the line of the apsides evidently coincided with the line of the equinoxes, which is computed to have been about 4,000 years before the birth of Christ, at which time chronologists have fixed the first residence of man upon the earth. The luminous year was then of the same length, at all latitudes, from pole to pole.

Though the annual duration of sunlight thus varies from age to age, and in the northern hemisphere differs from the southern; yet, such is the law of the planet's elliptic motion, that the sun's annual

intensity at any latitude north, is precisely the same as at an equal latitude south of the equator. This immediately follows from the formula, where the annual intensity is developed in a series of powers of *cos L*, which is always positive, whether the latitude *L* be south or north.

Proceeding with the investigation, I have computed the annual duration of sunlight, according to the rising and setting of the sun's centre, without regard to refraction. It is the half of 365.24 days, or 182.62 days, increased by the quantities in the following table, for the northern hemisphere, and diminished by the same for the southern hemisphere:

Annual Inequality of Sunlight, A. D. 1850.

Latitude.	Inequality.	Latitude.	Inequality.
0°	0 h. 00 m.	50°	24 h. 08 m.
10	3 25	60	36 51
20	7 07	70	66 52
30	11 23	80	86 02
40	16 40	90	92 01

Having thus determined the duration of Sunlight, let us next consider its increase by Refraction and by Twilight. The mean horizontal refraction, according to Mr. Lubbock's result, is 2075″, or 34′ 35″; the barometer standing at 30 inches, and the thermometer at 50° F. But as this is somewhat greater than what has been usually employed, we shall adopt 34′ as the mean value for determining the increase of daylight by direct refraction.

With respect to the duration of Twilight, A. Bravais, who has made extensive observations upon the phenomenon, observes in the *Annuaire Météorologique de la France* for 1850, p. 34: "The length of twilight is an element useful to be known: by prolonging the day, it permits the continuance of labor. Unfortunately, philosophers are not agreed upon its duration. It depends on the angular quantity by which the sun is depressed below the horizon; but it is also modified by several other circumstances, of which the principal is the degree of serenity of the air. Immediately after the setting of the sun, the curve which forms the separation between the atmospheric zone directly illuminated by the sun, and that which is only illuminated secondarily, or by reflection, receives the name of the *crepuscular curve*, or *Twilight Bow*.* Some time after sunset, this bow, in traversing the heavens from east to west, passes the zenith; this epoch forms the end of *Civil Twilight*, and is the moment when planets and stars of the first magnitude begin to be visible. The eastern half of the heavens being then removed beyond solar illumination, night commences to all persons in apartments whose windows open to the east. Still later the Twilight bow itself disappears in the western horizon; it is then the end of *Astronomic Twilight;* it is closed night. We

* The phenomenon is equally conspicuous in the west, before the rising of the sun, and in certain states of the atmosphere is scarcely less beautiful than the rainbow, for the symmetry and vivid tinting of its colors.

may estimate that civil twilight ends, when the sun has declined 6° below the horizon; and that a decline of 16° is necessary to terminate the astronomic twilight.

"I depart here from the general opinion, which fixes at 18° the solar depression at the end of twilight, and at 9° that which characterizes the end of civil twilight. The numbers which I have adopted are derived from numerous observations." "The shortest civil twilight takes place on the 29th of September, and on the 15th of March; the longest on the 21st of June. The shortest astronomic twilight occurs on the 7th of October, and on the 6th of March; the longest on the 21st of June, in this latitude. Above the 50th degree of latitude twilight lasts through the whole night at the summer solstice."

The analytic solution of the problem to find the time of the *shortest twilight* was first given by John Bernoulli; the formula may be found in various astronomical works. The method of Lambert for determining the height of the atmosphere from twilight being less commonly known, a method of solution is given in the Smithsonian Memoir. Lambert found that when the true depression of the sun below the horizon was 8° 03′, the height of the twilight arch was 8° 30′; and when the depression was 10° 42′, the altitude of the bow was 6° 20′.

With the given mode of calculation, the first observations of Lambert determine the height of the atmosphere to be 17 miles; and the second observations, 25 miles. And a still later observation would have given a still greater height, owing, perhaps, to the mingling of direct and reflected rays. The subject awaits further improvement; though some extensions have been made by M. Bravais, in the *Annuaire Météorologique de la France* for 1850.

If we regard only the appearance of the Twilight bow, the limits of the sun's depression assigned by M. Bravais are doubtless nearly correct, namely, 16° for astronomical, and 6° for civil twilight. But, regarding only the actual intensity of light falling upon the eye, it appears that the effects of the bow are further increased by indefinite reflection among the particles of air, and this may increase the average limits to 9° for civil, and 18° for astronomical twilight. Without determining which view ought to be adopted, a mean has here been taken, and *the following tables have been calculated on the assumption that the sun is* 7½° *below the horizon at the end of civil twilight, and* 17° *at the end of astronomic twilight.*

By subtracting either value from the latitude of the polar circle we obtain the lowest latitude at which twilight lasts through the whole night at midsummer. This latitude is about 50° for astronomical, and 60° for civil twilight. In determining these and other phases, the increase of the day by refraction and by the twilights may all be comprehended in one general formula.*

* Let m denote the sun's depression below the horizon at the end of either period; then the distance from the Pole to the zenith, $90° - L$, the distance from the Pole to the sun, $90° - D$, the distance from the zenith to the sun $90° + m$, or three sides of a spherical triangle are given to find the hour angle $H + \tau$, as in the following equation:

$$\cos. (H + \tau) = \frac{-\sin L \sin D - \sin m}{\cos. L \cos. D} = + \cos. H - \frac{\sin m}{\cos. L \cos. D}.$$

Here τ denotes the increase by refraction or by Twilight, according as m is taken at 34′, at 7½°, or 17°.

At the pole the duration of twilight is easily found by noting in the ephemeris the time at which the sun's declination south is equal to the depression of the crepusculum circle below the horizon; this instant and the equinox being its limits of duration. As before indicated, the limit of refractional light is when the sun is 34′ below the horizon; civil twilight when it is $7\frac{1}{2}°$; and common or astronomical twilight when it is 17°. Thus we shall find—

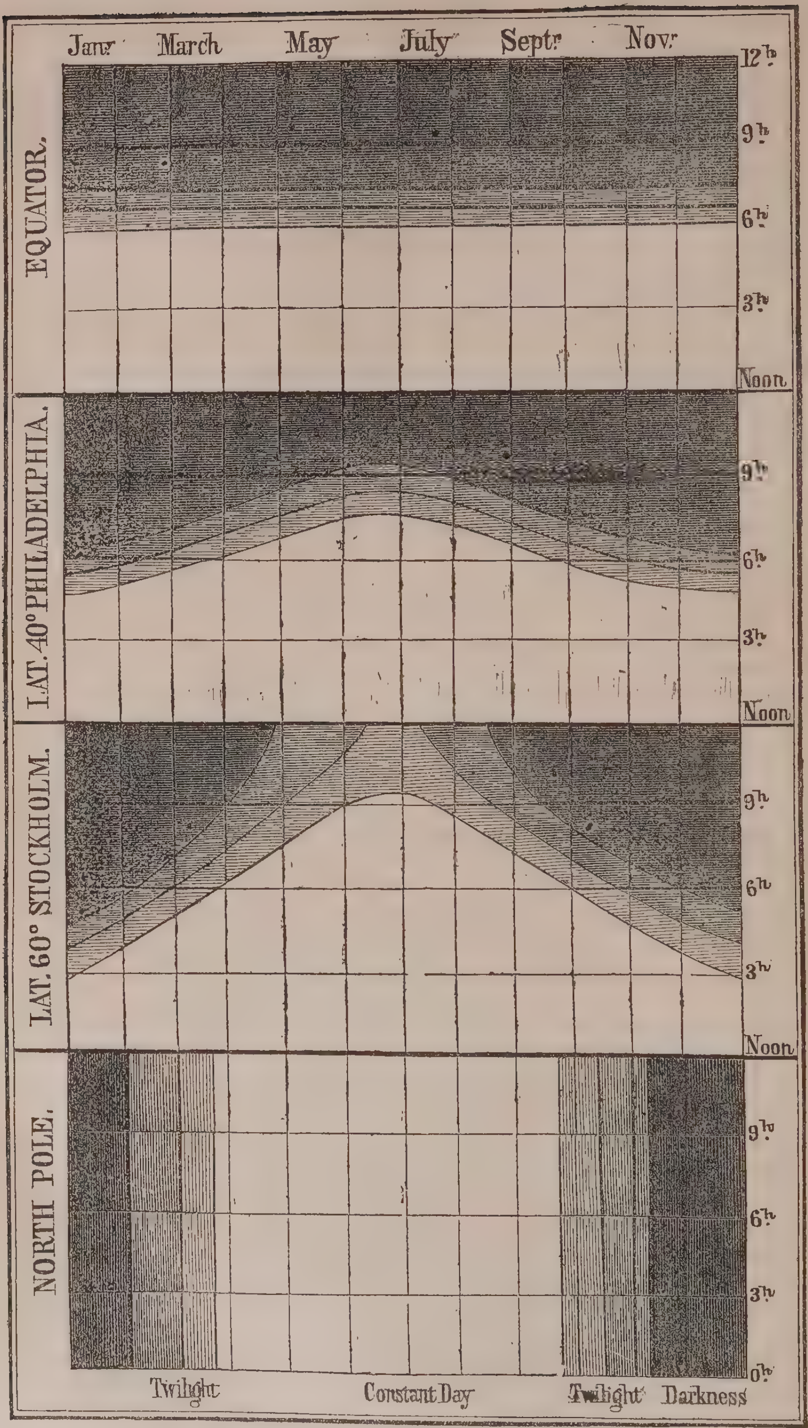
Annual Duration.

1853.	Sunlight.	Refractional light.	Civil twilight.	Astronomic twilight.	Darkness.
North Pole	186d. 11h.	2d. 22h.	38d. 15h.	94d. 16h.	84d. 3h.
Latitude 40°	183d. 8h.	1d. 14h.	21d. 6h.	49d. 2h.	132d. 20h.
Equator	182d. 15h.	1d. 5h.	15d. 21h.	36d. 1h.	146d. 14h.

From this table it appears that the annual length of darkness diminishes from the equator to the pole, while the duration of twilight increases from about one month on the equator to three months at the Pole. In this latitude about thirty-eight hours of daylight, at the sun's rising and setting, are annually due solely to atmospheric refraction. The second, fifth, and sixth columns represent $365^d\ 6^h$.

In further illustration of this subject, the duration from noon to midnight, or from midnight to noon, of sunlight, astronomic twilight, and darkness are exhibited to the eye in the accompanying plate for every day in the year on different latitudes. On the equator it will be seen that twilight has its least value and is almost uniform through the year. In the latitude of 40°, the limiting curves of twilight bend upward in an arch-like form. The upper curve at the same time recedes from the lower, and encroaches upon the duration of darkness, till, as shown for latitude 60°, twilight lasts through the whole night in summer. If the first and last extremities of the curves at January and December be united to complete the circuit of a year, darkness there will be represented by an elliptic segment, the longest nights and shortest days being at mid-winter. In approaching the highest latitudes, the lines which form the limits continually change their inclination, till, at the pole, they become perpendicular to their position at the equator.

The present section contains formulæ and tables for determining both the diurnal and the yearly limits of twilight for A. D. 1853, computed for 34′, 7° 30′, and 17°, depressions of the crepusculum circle below the horizon, the reasons for which have before been stated. Although these phenomena are varied by mists and clouds, and by the atmospheric temperature and density, still the assumption of mean depressions has been necessary in order to obtain a general view of their laws of continuance. The duration of moonlight, which is unattended by sensible heat, has not been discussed. From this source the reign of night is still further diminished, till, in this latitude, the


Jany
March
May
July
Septr
Novr
12h
9h
6h
3h
Noon
EQUATOR.
LAT. 40° PHILADELPHIA.
LAT. 60° STOCKHOLM.
NORTH POLE.
0h
Twilight
Constant Day
Twilight
Darkness

remaining duration of total darkness after twilight and moonlight, can scarcely exceed three months in the year. The interval towards the close of astronomic or common twilight corresponds to what is commonly termed, in the country, "early candle-light," when the glimmering landscape fades on the sight and the stars begin to be visible. The end of civil twilight marks the time at which some city corporations in Europe are said to have made regulations for lighting the street lamps.

In conclusion, without entering into further details, the connexion of solar heat and light has enabled us to exhibit, by the same formulæ and curves, the intensities of both in common. Indeed, so close is the analogy that even the monthly height of the mercurial column, which shows the temperature, indicates generally the average intensity of sunlight in that locality.

Half days, or Semi-Diurnal Arcs, in the Northern Hemisphere.

Date.	Lat. 0°.	Lat. 10°.	Lat. 20°.	Lat. 30°.	Lat. 40°.	Lat. 50°.	Lat. 60°.	Lat. 70°.	Lat. 80°.	Lat. 90°.
1853.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
January 1	6 00	5 43	5 24	5 03	4 37	3 58	2 51	0 00	0 00	0 00
January 16	6 00	5 44	5 28	5 09	4 45	4 11	3 13	0 00	0 00	0 00
January 31	6 00	5 48	5 35	5 18	5 00	4 33	3 49	2 04	0 00	0 00
February 15	6 00	5 51	5 41	5 30	5 17	4 58	4 29	3 29	0 00	0 00
March 2	6 00	5 55	5 50	5 44	5 36	5 26	5 10	4 40	3 00	0 00
March 17	6 00	5 59	5 58	5 57	5 56	5 54	5 51	5 46	5 32	0 00
April 1	6 00	6 04	6 07	6 11	6 16	6 22	6 32	6 51	7 49	12 00
April 16	6 00	6 07	6 15	6 24	6 35	6 50	7 12	7 59	12 00	12 00
May 1	6 00	6 11	6 22	6 36	6 53	7 15	7 52	9 12	12 00	12 00
May 16	6 00	6 14	6 29	6 46	7 08	7 38	8 28	10 50	12 00	12 00
May 31	6 00	6 16	6 34	6 54	7 19	7 55	8 58	12 00	12 00	12 00
June 15	6 00	6 18	6 36	6 58	7 25	8 04	9 14	12 00	12 00	12 00
July 1	6 00	6 17	6 36	6 57	7 23	8 02	9 09	12 00	12 00	12 00
July 16	6 00	6 16	6 33	6 52	7 17	7 51	8 51	12 00	12 00	12 00
July 31	6 00	6 13	6 28	6 44	7 04	7 32	8 19	10 20	12 00	12 00
August 15	6 00	6 10	6 21	6 33	6 48	7 09	7 42	8 53	12 00	12 00
August 30	6 00	6 06	6 13	6 21	6 31	6 44	7 04	7 43	10 14	12 00
September 14	6 00	6 02	6 05	6 08	6 11	6 16	6 23	6 37	7 18	12 00
September 29	6 00	5 59	5 57	5 54	5 52	5 48	5 43	5 33	5 03	0 00
October 14	6 00	5 54	5 48	5 41	5 32	5 20	5 02	4 27	2 20	0 00
October 29	6 00	5 51	5 40	5 28	5 13	4 53	4 22	3 14	0 00	0 00
November 13	6 00	5 47	5 33	5 17	4 57	4 29	3 43	1 46	0 00	0 00
November 28	6 00	5 44	5 27	5 08	4 43	4 09	3 09	0 00	0 00	0 00
December 13	6 00	5 43	5 24	5 03	4 37	3 57	2 49	0 00	0 00	0 00

Increase of the Half Day at Sunrise, or Sunset, by Refraction.

Date.	Lat. 0°.	Lat. 10°.	Lat. 20°.	Lat. 30°.	Lat. 40°.	Lat. 50°.	Lat. 60°.	Lat. 70°.	Lat. 80°.	Lat. 90°.
1853.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
January	2.5	2.5	2.6	2.8	3.3	4.4	6 7	0.0	0.0	0.00
February	2.4	2.4	2.5	2.7	3.1	3.8	5.1	9.0	0.0	0.00
March	2.3	2.3	2.5	2.7	3.0	3.8	4.6	7.0	14.0	0.00
April	2.3	2.4	2.5	2.8	3.2	3.8	5.0	8.0	0.0	0.00
May	2.4	2.5	2.6	3.2	3.5	4.5	6.1	22.0	0.0	0.00
June	2.5	2.6	2.8	3.1	3.7	4.9	7.6	0.0	0.0	0.00
July	2.5	2.5	2.7	3.0	3.5	4.7	6.7	0.0	0.0	0.00
August	2.4	2.5	2.5	2.8	3.2	4.0	5.2	9.7	0.0	0.00
September	2.3	2.4	2.5	2.7	3.1	3.7	4.6	7.0	14.7	0.00
October	2.3	2.4	2.5	2.7	3.1	3.7	4.9	7.5	24.3	0.00
November	2.4	2.5	2.6	2.8	3.2	3.9	5.9	16.3	0.0	0.00
December	2.5	2.5	2.7	2.9	3.5	4.6	7.5	0.0	0.0	0.00

Duration of Civil Twilight, Morning or Evening.

Date.	Lat. 0°.	Lat. 10°.	Lat. 20°.	Lat. 30°.	Lat. 40°.	Lat. 50°.	Lat. 60°.	Lat. 70°.	Lat. 80°.	Lat. 90°
1853.	m.	m.	m.	m.	m.	m.	h. m.	h. m.	h. m.	h. m.
January..........	32	33	34	37	43	57	1 16	3 21†	0 00	0 00
February	31	31	32	35	40	49	1 15	1 40	4 01†	0 00
March...........	30	30	32	35	39	50	1 03	1 29	3 04	12 00†
April............	30	31	33	36	41	50	1 08	2 08	0 00	0 00
May.............	32	33	34	42	45	58	1 37	1 10*	0 00	0 00
June............	33	34	36	40	48	64	2 46*	0 00	0 00	0 00
July.............	32	33	35	39	46	61	2 03	0 00	0 00	0 00
August..........	31	32	33	36	42	52	1 15	3 07*	0 00	0 00
September.......	30	31	32	35	40	47	1 02	1 35	4 42*	0 00
October	30	31	32	35	40	47	1 01	1 31	3 26	12 00†
November.......	31	32	34	37	42	51	1 10	2 16	0 00	0 00
December........	33	33	35	38	44	60	1 22	2 42†	0 00	0 00

Duration of Astronomical Twilight, Morning or Evening.

Date.	Lat. 0°.	Lat. 10°.	Lat. 20°.	Lat. 30°.	Lat. 40°.	Lat. 50°.	Lat. 60°.	Lat. 70°.	Lat. 80°.	Lat. 90°.
1853.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
January..........	1 13	1 13	1 17	1 24	1 39	1 56	2 38	5 29†	4 35†	0 00
February.........	1 10	1 10	1 14	1 20	1 30	1 43	2 20	3 32	7 49†	12 00†
March...........	1 08	1 09	1 12	1 19	1 30	1 48	2 21	3 44	6 29*	12 00†
April	1 09	1 11	1 15	1 24	1 36	2 01	3 06	4 01*	0 00	0 00
May.............	1 12	1 14	1 19	1 29	1 48	2 37	3 33*	1 10*	0 00	0 00
June.............	1 14	1 17	1 23	1 35	1 59	3 56*	2 46*	0 00	0 00	0 00
July.............	1 13	1 16	1 21	1 32	1 54	2 59	3 09*	0 00	0 00	0 00
August..........	1 10	1 12	1 16	1 25	1 40	2 11	4 18*	3 07*	0 00	0 00
September.......	1 08	1 09	1 13	1 18	1 31	1 51	2 30	5 23*	4 42*	0 00
October	1 09	1 10	1 13	1 19	1 29	1 47	2 18	3 25	7 48	12 00†
November.......	1 12	1 12	1 15	1 22	1 33	1 52	2 29	4 14	5 43†	0 00
December........	1 14	1 15	1 18	1 25	1 37	2 00	2 47	5 03†	3 33†	0 00

* Twilight through the whole night. † Twilight without day.

NOTE.—Astronomical Twilight includes the duration of Civil Twilight.

REPORT

OF

RECENT PROGRESS IN PHYSICS.

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[Translated from the German for the Smithsonian Institution.]

This work, which was commenced in the last annual report, p. 311, is continued in the present volume.

Some of the subjects discussed may be familiar to the readers of English scientific works, but these are retained for two reasons—firstly, because their omission would destroy the continuity of the narrative of scientific progress, and, secondly, because these very subjects serve as a text for the introduction of views held by continental philosophers, with very few exceptions, and yet not sufficiently well known to those who derive their information from the ordinary English works upon electricity.

SECTION FIRST.

FRICTIONAL ELECTRICITY.

ELECTRIC RELATIONS OF DIFFERENT SUBSTANCES, ELECTRICAL MACHINES, AND ELECTROMETERS.

§ I. ELECTRICITY OF MACHINE-MADE PAPER.—It has been long known that paper becomes electrified by friction ; and the excitation of electricity in the manufacture of machine paper is not a new phenomenon ; possibly there were few proprietors of paper mills who had not observed it, yet this phenomenon was described for the first time by *Haukel*.—(Pogg .Ann., LV, 477,)

In every machine the paper becomes highly negative on leaving the last pair of pressing rollers. If the finger is brought near to the paper, between the finishing rollers and the reel, a brush passes from it to the paper, and a Leyden jar can be readily charged. The paper, too, which has been wound upon the reel is electrified, and notably so when there is a large roll upon the reel. When the paper is cut off from the reel, and the long sheets are pulled apart, very strong, brilliant sparks pass between them.

This electricity evidently arises merely from the heating of the paper and its compression by the rollers. No rubbing friction can take place since the velocity of revolution of all of the rollers is exactly the same.

§ 2. SCHÖNBEIN'S ELECTRICAL PAPER.—By a process similar to that used in the preparation of gun-cotton, *Schönbein* has succeeded in converting paper into a perfectly transparent substance, which, by the slightest friction, becomes extraordinarily electrified, (Pogg. Ann., LXVIII, 159,) and which he employed in the construction of an electrical machine.

Such a substance must be in the highest degree acceptable to the experimental physicist, and it is so much the more to be regretted that *Schönbein* and *Böttger* have published nothing further on this subject, although electrical paper is now offered for sale in Berlin. In most cases the electrical paper can be replaced by thin sheets of gutta percha.

§ 3. ELECTRICITY OF GUTTA PERCHA.—Gutta percha is such a good insulator, and becomes so powerfully electrified by friction, that these properties of a substance, already applied to so many uses, could not long remain unknown. Towards the close of the winter in 1848, *Dr. Hasenclever*, of Aachen, called my attention to this peculiarity of gutta percha, and I had already used it in the construction of an electrophorus, when I found, in the March number of the Phil. Mag., a memoir by *Faraday* upon this subject, a translation of which appeared in Pogg. Ann., (LXXIV, 154.) The following is the substance of Faraday's remarks upon the electric and insulating properties of gutta percha:

A good piece of gutta percha insulates as perfectly as a similar piece of shellac, whether the form be that of a plate, a rod, or a mere thread; but, as it is tough and pliable when cold, as well as soft when warm, it serves a better purpose, in many cases, than the brittle shellac. In the form of strings and bands it is an excellent suspending insulator, and in that of plates it is the most convenient insulating support.

By friction gutta percha becomes powerfully negative. Some of it is sold in sheets no thicker than ordinary paper; if a strip of this be drawn between the fingers, it becomes so much electrified that it adheres to the hand and attracts bits of paper.

A plate of gutta percha makes an excellent electrophorus.

All kinds of gutta percha are not equally good insulators. If a piece of the proper kind is cut, the surface has a resinous lustre and a compact appearance, while a piece of the poorer kind has not the same degree of lustre, is less translucent, and looks almost like a solidified cloudy fluid.

If a piece which conducts is heated in a current of hot air or over a low gas flame, pulled out, folded up and then kneaded for some time with the fingers, as if to squeeze out the contained moisture, it becomes as good an insulator as the best kind.

A piece which insulates, will, if soaked in water for four days, reover its insulating power by an exposure to the air for twelve hours.

A piece which does not insulate is greatly improved after lying for eight days in a drying closet; the outer layer insulates, but a freshly cut surface shows that the inside still conducts.

Gutta percha of any kind exposed to a gradually increasing tem-

perature at 170 to 180° cent. gives out a considerable quantity of water, and after cooling insulates well.

§ 4. Electricity of rubbed glass.—It is well known that the kind of electricity which glass receives by friction depends upon the rubbing substance. But *Heintz*, (Pogg. Ann., LIX, 305,) has further shown that, by various means, glass may be brought into such a condition that by a slight rubbing it becomes negative, with substances which, under ordinary circumstances, make it positive.

If a glass rod be passed several times through the flame of a spirit lamp, (whereby every trace of adhering electricity must be dissipated,) and then rubbed gently with cloth, which ordinarily renders it positive, it becomes *negative*, and it is only after a continued and stronger friction that positive electricity appears.

It is not the heat of the glass rod which produces this effect, for if after having been passed through the flame the rod is allowed to become perfectly cold, or even laid aside for several days, it still becomes negative by slight friction with cloth.

This experiment shows that heat is not the *immediate* cause of the above mentioned phenomenon, but it might be possible that the heat of the flame was the cause of the condition of the surface of the glass, by virtue of which it became negative by slight rubbing. But *Heintz* has shown that even this is not the case.

If a perfectly clean glass rod be wrapped in tin foil, or put into a glass tube, and then held in the flame of a spirit lamp, so that the flame does not touch it, but still heats it, the above mentioned peculiarity does not appear, even if the temperature has been carried to a high degree.

In order to give to glass this peculiar property, it is not necessary to hold it within the flame, it is sufficient to pass it back and forth at a distance of about three inches above the top of the flame of a good spirit lamp with double current of air.

To clean the glass rod properly it should be washed with a solution of caustic potash, and rinsed with distilled water.

Other flames produce the same effect as that of alcohol.

The chemical action of the products of combustion cannot be the cause of this phenomenon, for steam does not produce it, but the flame of burning hydrogen does, and in this case nothing but the vapor of water is produced.

If a glass rod be dipped into concentrated sulphuric, muriatic or nitric acid, and rinsed after its removal with distilled water, until the drops no longer show an acid reaction, the adhering water thrown off, and what still remains allowed to evaporate—the rod acts precisely in the same way as it would have done if it had been passed through the flame of a spirit lamp, it becomes negative by friction.

Alkalies do not act like the acids, they cause the glass rod to become decidedly positive.

There is a great difference between the various specimens of glass in regard to the facility with which they assume the above described condition.

Upon rock crystal, calcspar, gypsum and heavy spar, the flame has the same action as upon glass.

On the other hand, such substances as ordinarily become negative by friction could not, by the employment of similar means, be so changed as to become positive.

In relation to the rubbing substance, it is shown by the experiments that for cloth, may be substituted leather, sealing wax or silk, but not Kienmaier's amalgam; on the other hand, a glass rod prepared in the flame of a spirit lamp and rubbed with tin foil shows negative electrcity; the same effect is produced by the other metals; even on dipping a prepared glass rod but once into mercury, it is drawn out with negative electricity; by repeated dippings, however, it is rendered positive.

To say "that the glass rod, held in the flame of any combustible substance, or dipped into concentrated acids undergoes a change upon its surface, which cannot be discovered immediately by the senses, but which can be recognized by means of the electroscope," can by no means be called an *explanation*, it is simply a modified statement of the fact.

§ 5. On the conducting power of certain substances.—*Riess* has examined many substances with reference to their conducting power, and their capability of becoming electrified by friction.—(Pogg. Ann., LXIV, 51.)

A small rod of *selenium*, three lines thick, will discharge a gold leaf electrometer almost instantaneously, and by means of it sparks may be drawn from the conductor of an electrical machine; insulated and rubbed in one spot by flannel, it becomes negatively electrified in every part. In its ordinary condition, consequently, the surface of selenium conducts. If in one spot a new surface is made by fusion, it does not conduct electricity as well as before, and a thread of selenium drawn out in a flame insulates as well as shellac. Rubbed with flannel, leather, linen, or even drawn between the dry fingers, such a thread becomes strongly negative.

Selenium, therefore, is a non-conductor, and becomes electric by friction, if its surface be perfectly clean.

Iodine is an imperfect conductor of electricity. A rod of this substance, $6\frac{1}{4}$ lines thick and $20\frac{1}{2}$ lines long, discharged an electroscope in one second; without insulation this cylinder could not be electrified; when insulated and rubbed against flannel it became feebly negative.

Retinasphaltum insulates, provided that pieces with a clear vitreous surface are used. Leather—brown pieces with a rough ragged surface, on the other hand, conduct, as is also the case with bits of amber having rough surfaces.

Aluminum and *glucinum* in the form of powder, when properly dried, are non-conductors.

§ 6. Production of electricity by steam escaping through narrow passages.—*Mr. Armstrong*, of Newcastle-upon-Tyne, towards the close of 1840, received information that, at Saghill, near Newcastle, a very extraordinary phenomenon had been observed on the escape of steam from a boiler. (Pogg. Ann. LII, 328, Phil. Mag. vol. XVII, p. 370 and 452, vol. XVIII, p. 50.)—Steam was escaping from a leaky joint near the safety valve, and the engine tender, having one hand acci-

dentally in the jet, had with the other taken hold of the lever to adjust the weight of the safety valve, when a spark passed between his hand and the lever, and he received a severe electrical shock.

Armstrong went to the place, and verified this statement; but the sparks were not so powerful as they had been before, which he ascribed to the circumstance that, the day before his arrival, the boiler had been cleaned by the removal of a thin calcareous incrustation; this, however, his subsequent investigations showed had no influence whatever upon the excitation of electricity.

In continuing his investigations, *Armstrong* stood upon an insulating stool, and found that then the sparks were much stronger. A metallic rod, with a brass plate at one end and a ball at the other, was held by an insulating handle, with the plate in the jet of steam; the whole insulated conductor showed signs of electricity, and sparks could be drawn from the knob. When the knob was brought within a quarter of an inch of the boiler, between sixty and seventy sparks passed in a minute. The greatest distance between the knob and the boiler at which a spark appeared was one inch.

The load upon the valve was thirty-five pounds to the square inch. The electrical excitement increased and decreased with the tension of the steam in the boiler.

The electricity of the steam and of the conductor held in it was positive.

Investigations made upon other boilers gave similar results; very powerful sparks were obtained from a locomotive. *Armstrong* stood upon an insulating stool, and took in one hand a light iron rod, which he held in the steam escaping from the safety valve. When the other hand was brought near an uninsulated conductor, he obtained sparks an inch long. The length of the sparks increased to two inches when the rod was held five or six feet above the safety valve.

Even from the cloud of steam in the engine house in which the locomotive stood, electricity could be drawn as by a lightning-rod from a storm cloud.

When the upper end of the rod held in the hand was provided with a brush of wire, sparks four inches long could be drawn from a knob on the lower end.

To discover the negative electricity corresponding to the positive of the escaping steam, the locomotive was raised from the rails, and its wheels placed upon insulating supports. Each of these supports consisted of three blocks of dried wood, covered with pitch, and separated by layers of pitch and paper. To avoid increasing the height, and at the same time to extend the insulating surface, the middle block was made much wider than the others. The water in the boiler was then made to boil. As long as the steam was confined, the boiler gave no signs of electricity; but as soon as it was allowed to escape, the boiler became strongly negative.

The sparks from the boiler were never more than one inch long, and this is easily understood when we consider that the electricity of the boiler, on account of the numerous angles and prominences of the locomotive, could not attain a high tension.

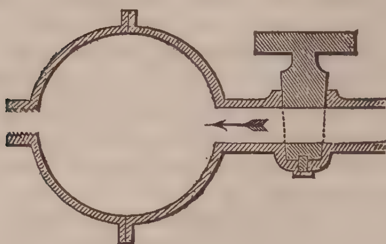
The experiments which *Armstrong* made to discover the source of

the electricity of steam boilers need not be described, as they led to no decisive results. We now pass to the investigations made by *Faraday* upon this subject.

§ 7. FARADAY'S RESEARCHES ON HYDRO-ELECTRICITY.—The substance of the results obtained by *Faraday* in these researches is given in my *Lehrbuch der Physik.*—(Vol. II, 2d pt., p. 82, 3d ed.) It is only necessary at present to give some of the details.

The apparatus employed by Faraday (Pogg. Ann. LX, 321) was not intended to produce steam in quantity, or of high pressure; his object being to discover the cause of the phenomenon, and not to increase the electric development. His boiler held 10 gallons of water, and would allow the evaporation of 5 gallons. To this boiler was attached a pipe $4\frac{1}{2}$ feet long and about $\frac{3}{4}$ of an inch in diameter, at the end of which was a globe about 4 inches in diameter, designated in the experiments as the *steam globe*, (fig. 1.) To this different mouth-pieces could be screwed. The boiler was well insulated.

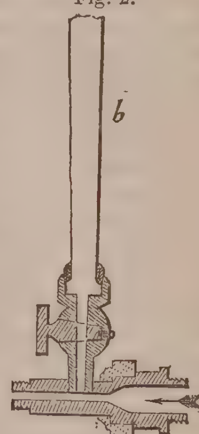
Fig. 1.



For a mouth-piece, a narrow boxwood tube may be screwed to the steam globe. If the globe contains no water, the issuing steam, after the first moment, and as soon as the apparatus becomes hot, excites no electricity. But if the globe contains so much water that it passes out with the steam, an abundance of electricity appears.

Instead of the boxwood tube, the apparatus represented in fig. 2 may be used. This consists of a narrow tube, into the upper side of which water may be allowed to enter from the small vessel *b* on opening the stop-cock *c*. If the steam globe contains no water, and the cock *c* is closed, no electricity is obtained when the steam escapes; but as soon as the cock is opened so that the water can drop into the issue pipe and be carried off with the steam, electricity is instantly developed.

Fig. 2.



Hence it follows that steam alone is not sufficient for the development of electricity; there must be condensed steam, consequently, drops of water, to rub upon the side of the escape pipe, or, in other words, the electricity is due entirely to the friction of the particles of water carried out by the steam.

If, instead of pure water, a very dilute solution of any salt or acid be employed in the apparatus shown infig. 2, the development of electricity ceases entirely.

This arises, as *Faraday* justly remarks, from the conducting power of water being so much increased by these agents that the electricity developed by its rubbing upon metal, or any other substance, is immediately discharged again. The case is just the same as if we attempt to excite shellac by flannel which is moist instead of dry.

As ammonia increases the conducting power of water only ina

small degree, *Faraday* concluded that a solution of ammonia, in the place of pure water, introduced into the escape tube, would still permit the development of electricity. Experiment verified this prediction.

The metals, wood, glass, shellac, sulphur, &c., become negative by the friction of the jet of steam and water, while the jet itself is positive.

An ivory tube, used as an issue piece, causes scarcely any electrical excitement, so that neither the boiler nor the jet is electrified.

When the neutral jet of steam and water is caused to impinge upon various substances, electricity is developed. If threads or strings of different kinds be stretched upon a fork of stout wire, and then exposed, when insulated, to the neutral jet, they become excited, as may be shown by the gold leaf electrometer. In this way, *Faraday* found that linen, cotton, silk, wool, yarn, &c., became negative by the friction of the unexcited jet.

When *Faraday* held an insulated wire in the jet, made positive by issuing from a glass or metal tube, at the distance of half an inch from the mouth of the tube, it was not excited; held nearer to the opening it became negative; removed to a greater distance, however, it was positive. The reason of this is, that the wire, when near the tube in the forcible part of the current, is excited and becomes negative, rendering the jet more positive than before; removed further off, in the quieter part of the current, there is no sensible excitement by friction, and the wire then acts only as a conductor to the positive jet, and shows the same state with it.

If some oil of turpentine be introduced through the stop-cock (fig. 2) into the escape tube, the boiler becomes positive, and the jet negative; if the stop-cock be closed again, the condition of things is soon reversed, as the oil is very rapidly dissipated. With olive oil, the phenomena are in general the same,—*i. e.*, the jet of stream and water becomes negative, the boiler positive; but this condition is more permanent, the oil not being volatile. A very little olive oil in the exit tube makes the boiler positive for a long time.

If a wooden tube be used as an exciter, and some olive oil applied to its inner end, or that at which the steam enters, the boiler becomes positive, and the issuing steam negative; but if the oil be applied to the outer end of the tube, the boiler becomes negative and the steam jet positive.

If a simple exit tube be screwed into the steam globe, the oil will produce the same effect as before, provided some oil be put upon the water in the steam globe; but if the latter contain no water and only oil, there will be no development of electricity.

Lard, spermaceti, beeswax, castor oil, resin dissolved in alcohol, and laurel oil act like olive oil and oil of turpentine.

Faraday thinks that these effects are to be explained by considering that the sides of the tube are rubbed, not by water, but by oil, each globule of water being covered by a very thin film of oil.

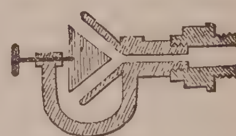
In confirmation of this view, that the oil spreads in thin films upon the surface of the water, he has shown that the addition of acid or salt, which in other cases prevents any excitement of electricity, in

the presence of oil does not have this effect; that is, when oil is in the escape tube, electricity is developed if the water be slightly acid or saline.

I do not, however, see among these facts a single one opposed to the view which seems to me to be at least more natural, namely: that we have not to consider the friction of the oil on the sides of the tube, but that of water on the sides affected by the oil; a view which *Faraday* does not entirely exclude, when he says: "It is very probable that when wood, glass, or even metal is rubbed by these oily currents, the oil may be considered as rubbing not merely against wood, &c., but against water also," &c.

When, from a vessel containing compressed air, a jet was caused to impinge upon a cone of wood or brass, placed in front of the opening, as shown in fig. 3, *there was no indication of electricity as long as the air was perfectly dry; but whenever the air was moist, the cone became negative.* *Faraday* ascribes this excitation of electricity to the particles of water which were condensed by the expansion and cooling of the air striking against the cone. These particles were visible both in the mist which appeared and by their moistening the surface of the wood or metal.

Fig. 3.



If the current of air carried particles of water which it had taken up in its course against the cone, the latter, as might have been expected, became negatively excited.

If the current of air carried with it the powders of different substances, these, too, were found to excite electricity. Flowers of *sulphur*, for instance, made wood and metal negative, pulverized *quartz* made both positive. Other substances, such as pulverized resin and gum, gave variable results.

§ 8. Excitation of electricity by the escape of liquid carbonic acid.—On a strong glass support, by means of a wooden attachment, *Jolly* insulated *Natterer's* condensation apparatus, with the exit pipe directed downwards. When the opening was unscrewed, and the liquid carbonic acid escaped, the apparatus became electric, and small sparks could be drawn from it.

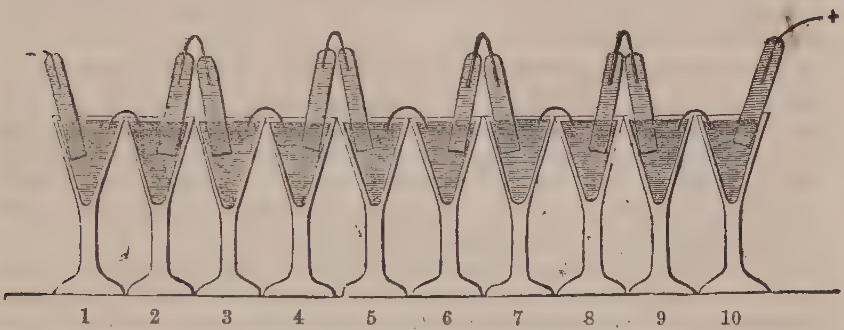
§ 9. Armstrong's hydro-electric machine.—A description of this machine will be found in my *Lehrbuch der Physik,* (Müller's Physics.) Compared with the largest and best plate machines, it does not excel so much by a greater tension, as by its affording a far greater quantity of electricity. The length of the sparks is not greater than in the most remarkable plate machines, but experiments which require, in a short time, a great quantity of electricity, are rendered much more striking by the hydro-electric machine.

The greatest power is developed when the electricity is drawn off in the form of a current without disruptive discharge. Thus the true electrolytic decomposition of water, which had never before been accomplished unequivocally by frictional electricity, was performed in the clearest and most distinct manner by the hydro-electric machine.

Ten wine glasses were arranged in a row. They contained—

1 and 2, distilled water.
3 and 4, distilled water + $\frac{1}{6}$ vol. sulphuric acid.
5, solution of sulphate of soda, reddened by acidified litmus.
6, solution of sulphate of soda, made blue by litmus.
7, solution of sulphate of magnesia reddened by acidified litmus.
8, solution of sulphate of magnesia made blue by litmus.
9, distilled water reddened by acidified litmus.
10, distilled water made blue by litmus.

Fig. 4.



Glass tubes, $3\frac{1}{2}$ inches long, and closed at one end around platinum wires passing into them some distance, were filled with the respective fluids and connected by means of the wires, (fig. 4,) as shown in glasses 2 and 3, 4 and 5, 6 and 7, 8 and 9, while 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10 were connected by wet cotton threads; two of the above described tubes were placed, one in No. 1, the other in No. 10. The wire of the tube in No. 1 was connected with the boiler, and that of the tube in No. 10 with a leaden water pipe leading into a well.

As soon as the steam electric machine was put into operation, bubbles of gas appeared upon all the wires, but upon the negative in exactly double the volume of those upon the positive wire; subsequent examination showed the former to be hydrogen and the latter oxygen. After two or three minutes, the water in glass No. 9 became blue around the wire, and that in No. 10, red; similar changes of color appeared, but not so soon, in the solutions of glauber salt and of epsom salt.

The experiment was continued until the tension of the steam was reduced from 75 to 40 pounds per square inch. The steam was then shut off and the boiler kept closed until the original tension was again reached, when the experiment was repeated with the same result.

In similar experiments, *Armstrong* carried the current through only two glasses filled with distilled water, when the well known phenomenon of the voltaic battery appeared; the level in the glass containing the negative pole rose considerably, while it fell in the other.

Another interesting phenomenon was then observed. When the two glasses were filled to the brim with water, brought within 0.4 of an inch of each other, and connected by a moistened silk thread, a quantity of which was coiled up in the water of each, the following phenomena were noticed:

1. A column of water enveloping the thread immediately passed between the glasses, and the silk thread was quickly drawn over from the glass connected with the negative pole into the one containing the positive pole, or that which led into the ground.

2. After this had taken place, the column of water continued for a few seconds suspended between the glasses without the support of the thread, and when it broke, the electricity passed in sparks.

3. When one end of the silk thread was fastened in the negative glass, the water diminished in the positive glass and increased in the negative; showing apparently that its motion was opposed to that of the thread when free to move.

4. By scattering particles of dust upon the surface of the water, it was ascertained that two opposite currents passed between the glasses: an inner one from the negative to the positive, and an outer one, enclosing the other, from the positive to the negative. Sometimes the outer current did not pass over into the negative glass, but trickled down on the outside, and then the water did not increase in the negative glass, but diminished in both.

5. After many fruitless attempts, the water was made to pass from one glass to the other for several minutes without the help of a thread. At the end of this time, no material variation in the quantity of water in either of the glasses could be detected. Hence it appears that the two currents were nearly, if not exactly equal, when the inner one was not retarded by the friction of the thread.

For the success of these experiments, it is essential that the water should be chemically pure. The least impurity caused the water to boil on the thread, which, becoming nearly dry, is destroyed by the heat developed by the current of electricity.

Other chemical effects, such as the precipitation of copper, from its solutions, upon silver, the decomposition of iodide of potassium, &c., were well shown by this electrical machine.

Finally, the electricity developed by steam, when conducted through a coil of wire, deflected the magnetic needle and magnetized a cylinder of soft iron.

§ 10. THE SOURCE OF ATMOSPHERIC ELECTRICITY STILL UNKNOWN—. Long ago *Volta* and *Saussure* expressed the opinion that the atmospheric electricity might have its origin in the evaporation of water, and supported this view by experiments showing the development of electricity by evaporation. Their experiments, however, did not always give constant results. The source of this uncertainty seemed to have been discovered by the investigations of *Pouillet;* according to his experiments, the development of electricity does not take place on the evaporation of pure water, but on the evaporation of water holding in solution salt, acid, or alkalies.

In the first edition of my work, based on *Pouillet's* Physics, these experiments are noticed on page 521 of the first part. Even then these experiments did not appear to me to be conclusive; they seemed to have been made without following the precautions necessary to the establishment of *Pouillet's* views beyond doubt; and hence I was led to conclude the paragraph with the expression of the hope that a *critical* revision of these experiments might be made. In the later edi-

tions of my *Lehrbuch der Physik*, the whole paragraph was omitted, its matter seeming to me too problematical, and therefore unsuitable for a text book.

The discovery of *Armstrong*, and the investigations of *Faraday* upon the development of electricity by escaping steam, gave a new point of view for the interpretation of *Pouillet's* experiments, which led *Reich* and *Reiss* to repeat them, and thus to discover the true relation of the conditions concerned in the case.

Reich has published his experiments in the *Abhandlungen bei der Begründung der konigl. sächsischen Gesellschaft der Wissenschaften, &c.* Leipsic, 1846, p. 199.

He verified the experiment as described by *Pouillet*. A clean platinum crucible is insulated and connected with a sensitive electroscope, first heated and then removed from the source of heat; if then pure water be dropped into it and allowed to evaporate, no electricity is obtained, either with or without the condenser.

But if a solution of common salt be dropped into the hot crucible, as long as the drop rolls about in the spheroidal state, by reason of the high heat of the crucible, we obtain, as before, no electricity, or, at most, but a mere trace of it; but as soon as the crucible has cooled enough to allow the liquid to boil away, the electroscope is charged with negative electricity, and pretty strongly, too, if the crucible is a large one.

The use of the condenser has hardly any advantage, as nearly the same results are obtained without as with it.

This, and the fact that the development of electricity commenced as suddenly as the boiling, were considered by *Reich* as decidedly supporting the view that the electricity is not owing to evaporation, but has its origin solely in the friction of the particles of water dashed about upon the hot sides of the crucible.

Now, if friction is the source of the electricity, it is clear that a powerful development of it can only take place when the particles of water are thrown about with violence. As the liquid is dropped into the vessel, traces of electricity sometimes appear, because, as this is done, a few particles of water are occasionally thrown out.

The electricity developed by the friction of the drops thrown out upon the sides of the vessel has sufficient tension to cause the divergence of the gold leaves of the electroscope, but the development is not continuous; hence the condenser is of no use.

The non-appearance of electricity when pure water is employed is easily explained; for, with the solution of salt, the violent boiling commences when the sides of the vessel have a far higher temperature than they have when pure water begins to boil. When the particles of pure water are thrown off they touch the sides of the vessel, already cool enough to be moistened by them; but when the solution of salt is used, the sides are so hot that the drops roll off.

In a platinum crucible, properly connected with an electroscope, *Reich* raised quartz sand, bit of porcelain, rusted iron filings, &c., to a red heat, removed the lamp, and sprinkled these substances with pure water. Under such circumstances a very perceptible evolution of electricity took place, while when the crucible was empty not a trace was found.

Riess, in a short paper, (Pogg. Ann., LXIX, 286,) says that the memoir of *Reich* recalled similar experiments made by himself as early as 1844, among which he cites the following as particularly striking and instructive:

A platinum spoon, with a round mouth, holding 0.24 grammes of water, was insulated and connected by a wire with *Behren's* and *Fechner's* electroscope. The spoon was raised to a white heat by a spirit lamp placed beneath, the lamp rapidly removed, and a quantity of solution of salt, nearly sufficient to fill the spoon, was then introduced by a pipette. The liquid passed into the spheroidal state, rotated, and, when the cooling had reached a certain point, was thrown out of the spoon with violent ebullition. During the whole course of this experiment no electricity showed itself.

A strip of platinum foil was rolled into a cylinder seventeen lines long and five in diameter, and placed over the cavity of the spoon: the previous experiment was then repeated. On the violent boiling of the fluid so much —E. was produced that the gold leaf struck the opposite pole.

This experiment, which can always be repeated with the same result if the surface of the platinum be previously freed from the salt deposited, teaches us that in *Pouillet's* experiment the source of the electrical excitement is not in the chemical separation brought about by the evaporation, but in the *friction* of the finely divided particles of fluid upon the sides of the vessel, provided that the fluid rolls over the sides without wetting them.

By slow evaporation *Riess* could never obtain a trace of electricity, neither could *Reich* develope any by evaporation under the boiling point.

All of the experiments which *Reich* made to discover a possible development of electricity by the condensation of steam gave uniformly negative results.

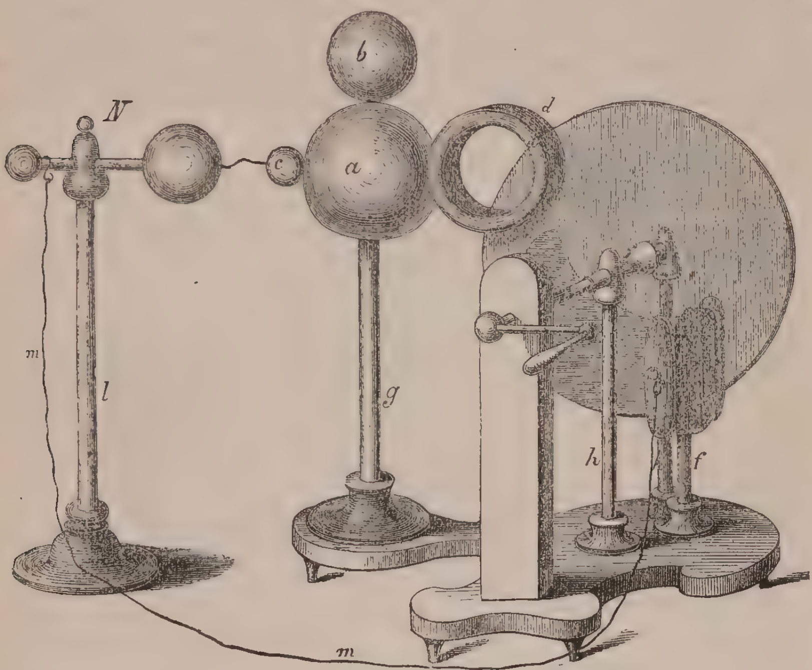
Riess also repeated *Pouillet's* experiments on the development of electricity by the *process of vegetation*. An insulated porcelain vessel was filled with loam, and cresses sowed in it. The earth, always kept moist, was connected by a brass wire with the collecting plate of a six-inch condenser. The condensing plate, when raised, was tested by a pile electroscope. From March until April, 1844, *Riess* caused cresses to germinate eleven times, examining the condenser daily until they had reached the height of two inches. Traces of electricity were often found, but not of a constant kind. Some check experiments, with earth alone, made it probable that even these traces did not arise from the vegetation.

From all of these experiments, it follows *that the opinion, that in evaporation and in the process of vegetation are to be found the sources of atmospheric electricity, is altogether without experimental foundation.*

§ 11. THE ELECTRICAL MACHINE.—The electrical machine belongs to the most common and best known of physical apparatus, and yet powerful machines can rarely be obtained at a moderate price. On this account, I think it will be interesting to many to learn the mode of construction according to which *Carl Winter* (electrician, &c., Wieden, Waaggase No. 501, Vienna) makes machines of excellent performance and at a very reasonable price.

Fig. 5 represents a machine, about one-ninth its actual size, with a 15-inch plate, giving sparks seven to nine inches in length. The axis *i* of the plate, as well as the supports *h g f* and *l*, are of glass. The rods *h* carry the axis of the plate, *f* bears the rubber, *g* the conductor, and *l* the discharger.

Fig. 5.



The prime conductor *a*, the spheres *b* and *c*, are all of sheet brass. To diminish, as far as possible, the loss of electricity by the support *g*, the conductor *a* has the form advantageously used in the great Harlem machine by *Van Marum*, as shown in section in fig. 6.

The conductor carries two wooden rings *d*, between which the plate revolves. These rings are of polished wood, and are provided, on the sides opposite the glass plate, with strips of tin foil, from which the collecting points project. These strips are continued to the conductor *a*, to which they carry the collected electricity.

From the bulb *b* projects a wooden rod about one inch in diameter, and rather more than a foot long; to this is attached a wooden ring about two feet in diameter, whose section is equal to that of the rod. Both the rod and the ring are covered with tin foil.

The discharger N is connected with the conductor of the rubber by a metallic cord *m*, enveloped in silk ribbon.

To obtain negative electricity, we have only to detach the cord *m* from the conductor of the rubber, and put the conductor *a* in connexion with the ground.

The arrangement for holding the rubber is shown detached in fig. 7. Upon the glass rod *f* stands the fork-shaped piece of wood

n, on the inner sides of which there are mortises for the reception of the rubber; along the middle of the face of *n* there runs a strip of tin foil which receives the electricity from the spring of the rubber, and leads it to the negative conductor *o*.

The rubber itself is shown in fig. 8, the oiled silk attached to it being omitted. *p* is a wooden slide which goes into the mortise of the support *n*. *q* is a projection which prevents the rubber from slipping out. Upon the slide *p* the amalgamated leather *r* is fastened. When the rubber is slid into its place, the metallic spring *s*, screwed by its narrow end to *p*, is compressed, and thus forces the rubber against the glass plate.

Fig. 6.

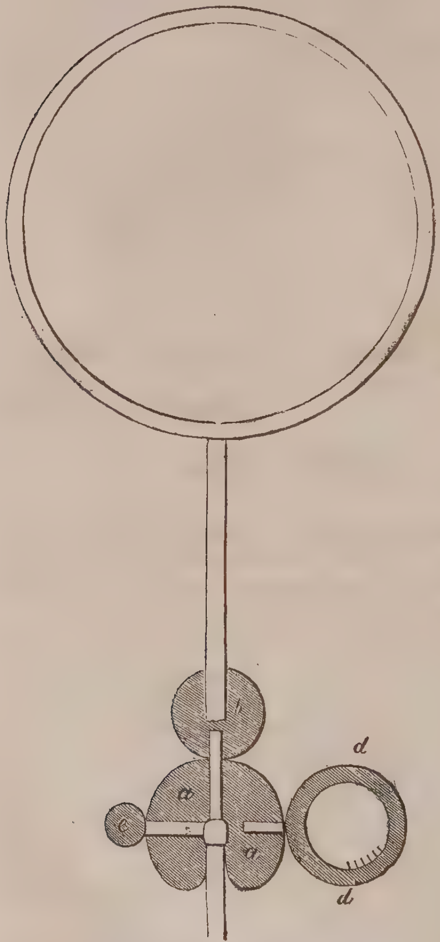


Fig. 7.

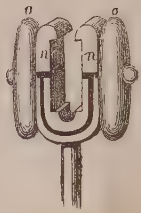


Fig. 8.

In the middle of the projection *q*, a strip of tin foil is seen; this leads from the amalgamated side of the leather to the spring *s*, from which the electricity is conveyed to the conductors *o* in the manner above described.

Fig. 9.

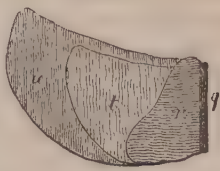


Fig. 9 represents the rubber as seen from the amalgamated side of the leather, with its two flaps of oiled silk, *t* being single and *u* double.

With remarkable power, *Winter's* machines combine, as we have just seen, great simplicity of construction.

The following are the prices of *Winter's* machines, with the discharger:

Size of plate.	Length of spark.	Price.	
		Florins con.	U. S.
40 inches	22 to 24 inches	300	$150
36 inches	20 to 22 inches	200	100
30 inches	16 to 18 inches	160	80
24 inches	12 to 14 inches	80	40
18 inches	9 to 10 inches	60	30
15 inches	7 to 9 inches	50	25
12 inches	5 to 7 inches	40	20
10 inches	4 to 5 inches	30	15
8 inches	3 to 4 inches	20	10
6 inches	2 to 3 inches	12	6

Machines of similar construction and equal power, but less elegantly finished:

Size of plate.	Price.	
	Florins con.	U. S.
18 inches	50	$25
15 inches	40	20
12 inches	30	15
10 inches	20	10
8 inches	16	8
6 inches	10	5

Winter has really displayed great taste in the arrangement of electrical apparatus, and has given a new and better form to many electrical experiments and toys.

He has constructed Leyden jars of extraordinary striking distance, of which more will be said in another place.

That he has succeeded in telegraphing and in kindling powder at a distance of 15,600 feet with frictional electricity, shows with how much certainty he can experiment with his apparatus.

I have satisfied myself in Vienna as to the power of the machines made by *Winter*. With the greatest readiness he has, at my request, furnished me the opportunity of giving the above description of his machines.

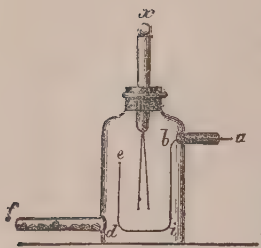
Gruel, of Berlin, makes cylinder machines of a peculiar construction, which are said to be of great power; but of this I know nothing

from personal observation, and his catalogues give no information upon this point.

§ 12. Improvement in the gold leaf electroscope.—*Andriessen* has introduced a contrivance into the gold leaf electroscope, by means of which its sensitiveness, and at the sametime its usefulness, is greatly increased.—(Pogg. Ann., LXII, 493.)

The glass vessel in which the gold leaves hang, is pierced at about the height of their point of suspension, and through this hole a polishedbrass wire, *a b i d e*, of ½ to ¾ lines diameter is introduced, fastened where properly insulated, and bent as shown in fig. 10. The plane, which the wire forms, must coincide with the plane of motion of the suspended leaves, so that when they diverge one may move toward *b i*, and the other toward *e d*.

Fig. 10.



The horizontal distance of *b i* from *d e* should be 1¼ inch; the length of the gold leaves 2 inches; their breadth as narrowas possible, about 1 line; the distance of their lower end from the horizontal wire, *d i*, ½ an inch.

If electricity be communicated to the wire—for instance, the negative electricity of a smooth piece of cork rubbed on a cloth—the leaves diverge, because the wire acts inductively and attracts the + E in the leaves, while the repelled — E is driven back to the knob *x*. The divergence of the leaves increases somewhat when the knob *x* is touched by a conductor.

The apparatus is now prepared to indicate the slightest amount of electricity; if a very small quantity be communicated to the knob *x*, the leaves either diverge further or collapse, according to the nature of the imparted electricity; they will collapse if — E be communicated to the knob, and diverge if + E is applied.

The apparatus is sufficiently sensitive to serve for the fundamental experiment of *Volta* without a condensor.

If a plate of zinc be substituted for the knob, its upper surface having been freshly rubbed with powdered pumice-stone, and a similarly prepared copper plate be placed on the zinc, when the copper plate is removed, the gold leaves will diverge.

If, on the contrary, the copper plate be screwed on in the place of the knob *x*, the suspended leaves will collapse on the removal of the zinc plate.

Andriessen observed that, by using a bell-glass electroscope of ordinary dimensions with the induction wire, the experiment never succeeded so well as when he used narrow bottles; hence, for his experiments, he employed ordinary bottles with ground stoppers 2 to 2½ inches wide, and about 4 inches high. He could give no explanation of this fact.

It was of great importance for the success of the experiment that the air inside the bottle should be perfectly dry; to accomplish this, *Andriessen* made a second hole in a suitable part of the bottle, into which he fitted a glass tube (*f*) filled with chloride of calcium. But

if the openings were well secured with cement, it sufficed merely to lay a piece of the chloride of calcium in the vessel.

The combination of this apparatus with the condensor gave rise to peculiar difficulties; if a collector be screwed to the top instead of the knob x, and the condensor plate placed on this, the electricity of the gold leaves will be drawn mainly into the collector plate when the condensing plate is touched, so that the leaves will diverge as soon as the condensor is raised, even if not the least electricity has been imparted to the collector.

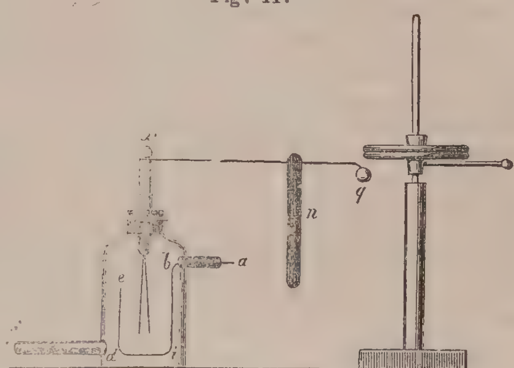
This circumstance renders the use of the condensor, in the ordinary manner, altogether uncertain. *Andriessen* remedied this defect in the following way:

He placed the condensor, not upon the electroscope, but beside it. A glass tube fastened to a board and coated inside and outside with shellac, carried the collector as shown in figure 11.

When the electricity is condensed on the collector, the condensor is raised, and the collector with its free electricity is brought into connexion with the electroscope by means of the wire $x\ q$.

This wire is of soft copper, and is wound around the stem of the knob x, which sustains the gold leaves; n is a stick of shellac fastened to the wire, serving as a handle to bring the end q of the wire into contact with the collector.

Fig. 11.



§ 13. Improvements in Coulomb's torsion balance.—Since the time of *Coulomb*, the electric torsion balance has been used by very few and with but little effect; complaints were made of the uncertainty of the instrument, and of its difficult management; the opinion spread abroad that exceedingly great skill was required in the experiments to produce reliable results with it.

Riess opposed this prejudice (Pogg. Ann. LXXI, 359;) he experimented much with this balance, and proved that, if the necessary care has been taken in the construction of the instrument, the result will not only be certain, but excessive skill in its use will not be required.

The instrument which *Riess* describes in the above mentioned communication has the dimensions of the smallest balance which *Coulomb* used in his measurements. The lower glass cylinder is one foot in diameter and one foot high; the tube in which the metallic thread hangs is fifteen inches long. The torsion balance of *Riess* is constructed on the same principle as that of *Coulomb*, but a few arrangements are introduced which render a greater accuracy of observation possible; thus the position of the moveable arm or beam is observed with a microscope. To make the most minute changes in the torsion of the metallic wire, a micrometer screw is placed at the head of the apparatus, and is turned by means of a dependent handle with a

Hook's universal joint, while the position of the moveable beam is observed at the same time by the microscope. In this manner the most accurate readings are possible. It would have been of advantage to those about to construct such an instrument, if the author had given, with his other drawings, a section through the upper part of the apparatus.

If the greatest possible care has been taken in the construction of all the separate parts, and, above all, when the moveable beam, as well as the handles of the proof planes, or knobs introduced into the apparatus, are insulated as perfectly as possible, very great accuracy in measuring may be expected. The torsion balance, however, is a contrivance which is not altogether adapted to lecture experiments, its principle is sufficiently well known, and the detailed description of the instrument interests only the few who are practically engaged in measuring the density of electricity. For this reason, I do not consider it necessary to dwell further upon the subject here.

With reference, however, to the method of observation and computation of the results, something may be given from *Riess's* memoir.

To determine the ratio of two electrical densities at a and b, existing at the same time upon two parts of *one* conductor, or upon two conductors, *Coulomb* made a whole series of measurements (generally five) alternately for each place, and as nearly as possible, in equal intervals of time. In this manner he obtained, for the first place, three densities, (measured by the angle of torsion at equal elongations of the balance beam,) a, a', a''; and two values for the density in the other place, b and b'. The measurement of b was made between those of a and a'; and that of a', between those of b and b'; thus the mean of a and a' could be considered as nearly simultaneous with b; the mean of b and b' with a', &c. The required ratio of the two densities is expressed by

$$\frac{\frac{1}{2}(a + a'),}{b} \quad \text{or} \quad \frac{a'}{\frac{1}{2}(b + b'),} \quad \text{or} \quad \frac{(\frac{1}{2}a' + a'').}{b'}$$

The mean of these three values is then taken as the true ratio, $\frac{a}{b}$ of the two densities. This method requires great skill; for it is not always easy to make the alternate measurements of density at equal intervals, besides exact results cannot be obtained if the two places examined are on two different bodies, one of which loses its electricity more rapidly than the other, for then the ratio of the two densities changes at every succeeding moment; hence the three quotients are no longer three values of the same quantity, differing only in consequence of unavoidable errors of observation, but three essentially different quantities, and the mean from the values of the three quotients, consequently, does not give the true ratio of the two electrical densities at any one moment.

Indeed, this method is not at all applicable where the same density cannot be determined twice as when the existence of the density b depends upon an alteration of the density a, a return to which is therefore impossible.

Riess employed the following method of observing with success, with two perfectly equal proof balls, having equally well insulated

handles, the two electrified places are touched *simultaneously*, or so rapidly one after the other that the contact may be considered as simultaneous. One of the proof balls is then placed in a large bell glass, the other applied to the torsion balance. After measuring the torsion for the first proof ball, it is removed and the second, (kept meanwhile in the bell glass,) is applied to the balance, and the corresponding torsion, (with equal elongation,) is measured. The times at which the two readings are made, are observed by means of a watch marking seconds. The torsion is now diminished a few degrees, hence the elongation is somewhat increased, and the length of time the balance beam occupies in returning to its former position is then noted.

An example may serve better to explain this method of observing. Suppose the two proof balls I and II have been applied to the places whose electrical densities are to be compared.

I being brought to the torsion balance requires a torsion of 55°.5, to bring the beam into a certain position, that is, deflected a certain number of degrees.

II is now applied. To bring the beam into exactly the same position as before, the thread must receive a torsion of 293°.5.

Between the first and second reading a period of 3.1 minutes has elapsed.

Now suppose the torsion is reduced 20° or to 273°.5, and, counting from the second reading, 3.2 minutes elapse until the beam returns to its former position.

We will now proceed to the computation of these data. In 3.2 minutes proof ball No. II has lost a quantity of electricity which is measured by a torsion of 20°; if the loss of electricity is proportional to the time, the loss of No. II between the first and second reading amounts to—

$$\frac{3.1}{3.2} \times 20 = 19^\circ.4;$$

but the loss of electricity is proportional not only to the time, but also to the density, which is not equal in the two periods. We may suppose, without sensible error, that the electrical density of proof ball II, in the first period, is to the density in the second period as 293.5 is to 273.5; hence the loss of ball II in the first period, (that is, between the first and second observations,) would be—

$$19.4 \times \frac{293.5}{273.5} = 20^\circ.8.$$

At the instant in which the electrical charge of ball I was measured in the balance, the charge of ball II was

$$293.5 + 20.8 = 314^\circ.3,$$

Hence, the required proportion between the two quantities of electricity is

$$\frac{55.5}{314.3} = 0.179.$$

If we indicate by a the torsion first measured, by b the second, by c

the number of degrees the torsion was diminished after the second measurement; also by t and t' the two intervals of time, then the density of the electricity on ball II, at the moment the torsion a was measured, is equal to

$$b + c \times \frac{t.b}{t'(b - c)} \qquad (1)$$

Suppose, for example—

$$a = 67^\circ \qquad t = 3'.7$$
$$b = 369^\circ \qquad t' = 2'.5$$
$$c = 20^\circ;$$

then, at the instant in which the density a was measured, the electrical density on the other proof ball was

$$369 + 20 \times \frac{3.7}{2.5} \times \frac{369}{349} = 369 + 31^\circ.3 = 400.3;$$

and the required ratio of the two densities

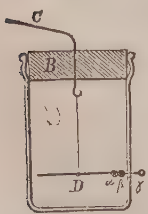
$$\frac{67}{400.3} = 0.167.$$

Riess computed the results by this method of observing "with pairs of proof bodies," not according to formula (1), which is only an approximation, but according to another approximate formula, the derivation of which, however, cannot be termed elementary. The results, however, of the computation, according to formula (1), correspond so closely with those obtained by *Reiss*, that there need be no hesitation in using it.

The results of the first of the above two examples corresponded perfectly when computed according to both formulas; in the second example, the value found, according to *Riess*, was 400°.8, while we have made it 400°.3, a difference which has hardly any effect upon the required quotient.

§ 14. Electroscopes to which the principle of the torsion balance is applied. In the 53d volume of *Poggendorf's Annalen* is a description of two electrometers, or rather electroscopes, which may be considered as small torsion balances; the first by *Dellman*, (page 606,) the second by *Œrsted*, (page 612.)

Fig. 12.



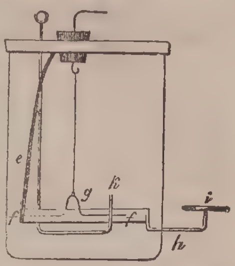
Dellman's instrument is represented in fig. 12. The mouth of a white preserve jar, 8 or 10 inches high, is closed with a piece of cork, B. Through this cork is passed a tolerably stout wire, C, with a hook at its lower end, in which is hung a thread of untwisted silk. The thread carries a small rod of shellac, D, with a little ball of elder pith, a, fastened at one end. (Pressure with *clean* fingers readily removes all angles from the pith.)

The glass is pierced at a, and a pin, $\beta\,\gamma$, is fastened in the hole by shellac, with the head, γ, outside; on the inside a pith ball, β, is stuck upon the pin, the point of which must not go through the ball. The wire, C, is drawn up until a and β are on a level; the wire is then

turned upon its axis once or twice, so that the ball a, by means of the elasticity of the thread, is brought against the ball β.

Dellman subsequently changed the construction of his instrument, and thus made it much more sensitive. Fig. 13 represents *Dellman's* electroscope in its new form, (Pog. Ann. LVIII, 49.) The moveable beam g consists of a light metallic wire, which is bent in the middle so that one-half of the balance beam can be placed on the right, and the other on the left side of the metallic strip f. This strip f extends through the middle of the apparatus, and is fastened on one side to the conducting wire h, on the other to the wire e.

Fig. 13.



If electricity be communicated to the conducting wire (on which a plate, such as that of a condensor, can be screwed) it will, in part, pass to the balance beam, (pressed by the torsion of the fibre against the metal strip f,) which is, consequently, deflected.

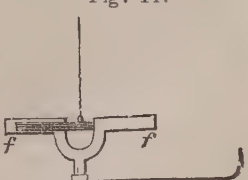
One vertical arm of the wire, k, whose horizontal part makes an angle of about 90° with the direction of the strip f, is on the right, and the other vertical arm on the left side of the beam. *Dellman* terms this wire, to which electricity can be communicated from above, and whose function is the same as the wire in the electrometer of *Andriessen*, the "cross wire." When electricity is communicated to the cross wire, the beam g at once turns and stands in a new position of equilibrium. It moves to one or the other side according to the kind of electricity communicated to the wire h. It is evident that the apparatus in this form must be exceedingly sensitive; but it is very troublesome, as the beam suspended by the silk fibre commences vibrating with the least disturbance.

The paper alluded to in *Poggendorf's Annalen*, in which *Dellman* speaks of the new form of his electroscope, is somewhat obscurely written. A particular description of the apparatus or of its application is not to be found. The proper dimensions for the strip and the best position for the cross-wire are spoken of without any allusion having been previously made to the cross-wire and strip. Evidently, *Dellman* takes for granted much that is not familiar to most of his readers.

The arrangement of the strip f is evidently somewhat awkward. *Romerhausen* has very advantageously altered it. The balance beam, which is of common flat gold wire, is straight, while the metallic strip f has a bend in the middle, as represented in figure 14.

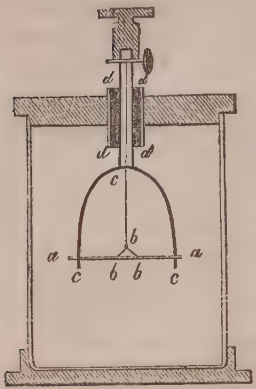
The metal strip is fastened at its middle to the conducting wire. In this instrument the torsion of the silk fibre is opposed to the repulsion of the beam, while in *Oersted's* electrometer the magnetism of a small iron wire tends to keep the beam in a given position.

Fig. 14.



The most important parts of *Oersted's* instrument are shown (one-half the natural size) in figure 15. In the cover of a glass vessel is a glass tube *d d*, in which a metal tube, insulated with shellac, is fastened and divided below into two bent arms, *c c*. In the middle of this tube hangs the silk fibre which carries the beam *a a*, made of a fine brass wire; *b b* is a stirrup of very fine iron wire, very slightly magnetized, by means of which the beam is pressed against the brass arms *c c*, so that one end of *a a* touches the left side of *c c* and the other end the right side. When electricity is communicated from above it is conducted from the arms *c c* to the balance beam *a a*, causing it to turn. If the magnetic directive power is very feeble the electrometer will possess great sensibility. To discover weak electrical effects, enough electricity is previously communicated to the instrument to cause the beam to diverge a few degrees. A substance, possessing the same kind of electricity, then produces a considerable increase of the deviation when brought near. The electricity, which insulated zinc and copper plates show, upon contact and separation, is thus rendered very perceptible, without the aid of a condensor. *Dellman's* instrument also shows this fundamental experiment of *Volta* without a condensor.

Fig. 15.



Oersted adapted to his instrument a contrivance for measuring the angle of deflection, and a microscope to observe the position of the beam more accurately, &c. I have omitted these as not necessary in explaining the principle of the instrument. *Oersted* himself used the instrument only as an electroscope.

Kohlrausch has converted *Dellman's electroscope* into an *electrometer*.—(Pogg. Ann. LXXII, 353.) He introduced under the beam a divided circle for reading the angle of deflection, and a second, at the top of the instrument, for determining the torsion. Instead of cocoon fibre he used a fine glass thread, because its force of torsion is more reliable.

Dellman's instrument has this great advantage, that it may be constructed with but a few and common materials, so that any one having but little dexterity can make such an instrument for himself. This advantage of *Dellman's* apparatus *Kohlrausch* has surrendered altogether, for his instrument can be made only by a skilful mechanic. However, if the apparatus in this form has advantages which it had not in its simpler form, no objection can be made. According to *Kohlrausch's* memoir, his electrometer serves for accurate measurement in cases for which the torsion balance of *Coulomb* is not sufficiently sensative. I cannot give a decided opinion as to the value of *Kohlrausch's* electrometer in this respect, for I have not experimented with it. I do not know whether the same amount of trouble is found in its use that must be required in its construction. The instrument seems to me to be rather complicated; but whether this view is well founded I must leave to the judgment of those who have made practical use of it. The results which *Kohlrausch* presented in his memoir are much in favor of his instrument.

In all electrostatic measurements it is quite certain that the most important source of error is to be found in the gradual loss of the electrical charge by the inductive action which the charged body has on those near it, &c. The uncertainty which springs from this source is certainly far greater than the errors of observation which arise from adjusting and reading. From this point of view it seems superfluous to apply to electrometers of all kinds a great array of graduation, microscopes, &c.

In the memoir already mentioned *Kohlrausch* suggests the very excellent idea of employing the electroscopic power of the voltaic pile as a convenient measure for frictional electricity, or for comparing different electrometers.

A pile of a given number of elements, consisting of strips of zinc and copper soldered together, immersed in small glass vessels containing distilled water, will have, if one pole be put into perfect connexion with the ground, a constant tension upon the other pole, and, consequently, will answer very well for comparing different electrometers. In a long immersion (lasting over a week) the intensity will certainly diminish, because the zinc becomes covered with oxyde, but the original intensity may be restored by cleaning the metal with a file.

Kohlrausch obtained from the pole of such a pile the constant indication of 52° to 53° of his instrument during a whole week. After the lapse of four weeks the indication had fallen to 46°, but it returned to the original quantity as soon as the metal was cleaned by filing.

§ 15. Petrina's electroscope.—*Petrina* has constructed an electroscope in which he has substituted an electrophorous for the dry pile. (New theory of the electrophorous, and a new resin-cake electroscope, by Dr. Franz Petrina, from the Abhandlungen der Königl. Böhmischen Gesellschaft der Wissenschaften, V. Folge, Bd. 4, Prag. 1846.) The gold leaves are suspended between two metallic plates, one of which is in connexion with the cover, the other with the insulated dish of a small rosin-cake electrophorous. By a special contrivance the mould, together with the cake, can be depressed, whereby one of the plates (that connected with the cover) receives a positive and the other a negative charge, so that the two plates here play the same part as the pole plates of the dry pile in *Bohnenberger's* electrometer.

It is, in fact, a very ingenious application of the electrophorous, and if we did not possess the pile electrometer, we should welcome the resin-cake electrophorous as an important addition to electrical apparatus; but whether this instrument, as compared with the pile electrometer, will receive any practical consideration, I am very doubtful. *Petrina*, indeed, thinks that it is easier to construct, because it is easier to make a good cake of resin than a good *Zamboni* pile; but the contrivance for raising and lowering the plate with the resin cake may quite make up for this difference. The only real advantage of *Petrina's* apparatus is, perhaps, this: that it can never become useless from loss of power, because the resin, when it becomes weak, can always be rendered electrical again.

With reference to the rest of the contents of *Petrina's* memoir, it should be discussed in another place; but I will not return to it again

because it does not present any new facts, but only opinions, the correctness of which is still very problematical.

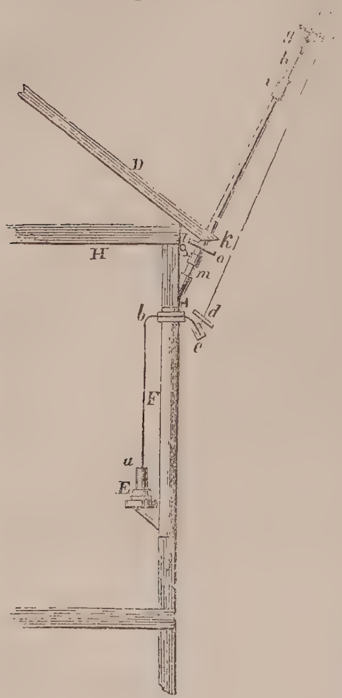


Fig. 16.

§16. Observation of Atmospheric Electricity.—*Romershausen* has constructed an apparatus for observing atmospheric electricity, the arrangement of which is exhibited in fig. 16. (Pogg. Ann. LXIX, 71.)

Fig. 16 represents the application of the *collecting apparatus* to any dwelling, and to any story of it.

H is the house, over the roof D of which the collector can extend without doing any injury. F is the window of the observer's chamber; *m n* represents the collecting rod in its general construction. It rests above the window in a strong iron socket *m*, and, by means of a hook *l*, is easily and firmly secured in a slot *k* in the roof. It extends obliquely from the house into the air, and its details are arranged as follows:

The rod of varnished pine wood, 10 or 12 feet long, is provided at *i* with a brass band, in which the solid glass rod *h*, 1½ feet long, and coated with shellac, is cemented. This supports, at its upper end, the collecting apparatus *g n*.

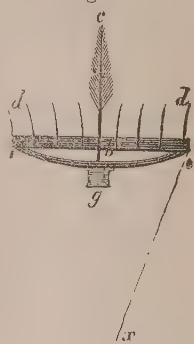
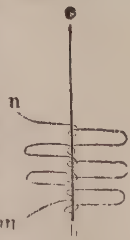


Fig. 17.

For greater clearness, this part is shown in section and on a larger scale in fig. 17. *a e* is a flat copper ring, five inches in diameter, on the inside of which are soldered colleeting wires *d d* of copper, gilded and brought to a fine point; these are inclined outward slightly, so as to appear like a crown. A copper support, passing across the ring, and curved somewhat downwards, bears on its underside the socket *g* for fastening on the glass rod *h*, and on the upper part a higher wire point is soldered. This point is the most important part of the whole contrivance, since it alone, according to exact experiment, renders sensible the slightest shades of atmospheric electricity.

Fig. 18.



The copper wire, finely pointed and gilded at its upper end, is about one Paris line in diameter, and is surrounded with very fine platinum points, which are most easily made in the following way: The wire is covered with tin solder as far as the platinum points extend; then, as shown in fig. 18, it is wound with the finest platinum wire, which is fused in a spirit lamp where it touches the upper point; the loops are then cut, and arranged as exhibited in fig. 17.

The conducting wire *d e*, fig. 19, [which is a repetition of fig. 17,] of copper, is soldered to the ring at *e*. At *d* it has a small tin plate which turns off the rain. A similar plate is placed on the rod at *o* for the same purpose. On the lower end of the conducting wire *e d* at *c*, a small copper socket is soldered and arranged so as to receive the conducting wire coming from the chamber. The window frame is bored in the corner, for the purpose of fastening the conductor in a glass tube well coated with shellac, and bringing it into the chamber perfectly insulated. At *b* the wire is bent downwards, and connected with the electrometer E placed at the side of the window, and beyond the immediate influence of the sun's rays.

Romershausen uses two electrometers, standing in the same case, namely: a pile electrometer, and one constructed on the plan of *Dellman*, which has been already described.

SECTION SECOND.

INDUCTION OF ELECTRICITY.

[This title is translated by words having a very different sense in English from those used in the German. The original is "*Verlheilung und Bindung der Electricität*"—literally, Distribution and Binding of Electricity. The verb *vertheilen*, which we translate by "induce," is so strictly parallel in all its derivatives with the corresponding English word that, although the original meanings are not the same, we need make no further remark upon this point.

But, although we may translate "bound" into "disguised," we cannot with equal propriety speak of an electrified conductor as "disguising" electricity in a body brought near to it; the German would say "binding." In some English translations of German works on electricity, the words "combine," "combined," and "combination," are used; these are not only incorrect, but lead to an idea diametrically opposed to the true one. In general for "bind" we have used simply "induce," sometimes the more precise periphrasis "render latent." In general "latent" and "disguised" are used synonymously.

A good English word nearly identical in meaning with the German one, and capable of being used in all the corresponding modifications, would be "engage"—thus we might speak of a conductor "engaging" electricity, of "engaged" electricity, and on the contrary of "disengaged" or free electricity.

But as there is no authority for the use of this term we have not ventured to introduce it.

These remarks are rendered necessary by the fact that in many places the force of the original is lost in the circumlocution required in the English.

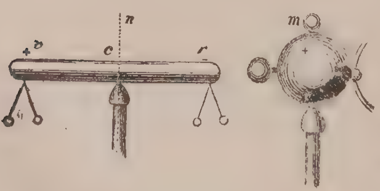
The introduction to § 26, and the first foot note after it, should be read wlth reference to these difficulties in the translation.

In strictness the term "latent electricitv" is improper as implying an analogy with latent heat. Even "disguised electricity" is not really correct, as it is one of the main objects of this section, to show that electricity in this condition loses none of its properties. But we may here refer to the remark of our author, that terms in themselves not strictly accurate, may be safely used after correct ideas have been connected with them.]

§ 17. INTRODUCTION.—The mode in which *Biot* has exhibited the induction of electricity on an insulated body, to which an electrified body is approached, should be sufficient to remove every doubt as to the nature of induction; yet a controversy on this subject has arisen, from the objection of *Pfaff*.

An account of this controversy is given in the second volume of *Dove's* Repertorium, page 29.

Fig. 20.



Let a body *m*, (fig. 20,) charged with positive electricity, be brought near an insulated conductor *c*, then will *c*, as it is well known, be electrified by induction; at the end nearest *m*, is to be found the attracted — E, and at the opposite end the repelled + E, as shown by the proof plane.

If the insulated conductor be touched, the repelled electricity will be conducted off, while the electricity attracted by *m* remains disguised or latent at *c*.

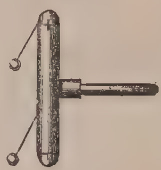
Pfaff contended that this disguised electricity could not act in all directions, while *Biot* showed its free activity by suspending at the two ends of the conductor electrical pendulums, which diverged; those at

one end, by the attracted electricity, and those at the other end, by the repelled. If the conductor was touched the distant pair of suspended balls collapsed, while the divergence of those nearest *m*, increased.

Although this experiment, if proper precaution be taken, such as not charging *m* too strongly, does not easily fail, yet it has not succeeded for many observers, and to this may be attributed the whole controversy on the nature of disguised electricity. The doubt about the experiment arises, as *Riess* has properly remarked, from the fact that the electricity of the inducing body acts at right angles to the electroscopic pendulums, which it causes to deviate from their perpendicular position.

Riess has remedied this defect by the following arrangement. A metallic rod about 5 inches long and 3 lines thick, with rounded ends, is fastened by the middle to an insulating handle, as shown in fig. 22, and by means of this handle is held in a vertical position. It is provided at both ends with a pith ball suspended by a linen thread.

Fig. 22.



If an electrified body be brought near the lower end both balls will be repelled. Suppose the approaching body is positively electrified, then the upper pendulum is deflected with + E, the under one with—E, as may be tested by presenting a rubbed glass or stick of sealing wax.

If the metallic rod be now touched, the upper pendulum falls, while the divergence of the under one is increased.

At the lower end of the rod, and in the ball there, only disguised — E is now found; the electricity of this end, though it is disguised, repels the like-named electricity of the ball; hence disguised electricity acts as freely at a distance as though it were not disguised.

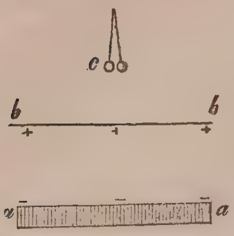
The divergence of the lower pendulum proves, that the particles of disguised electricity repel each other precisely in the same manner as though they were not disguised, consequently its propagating power is similar to that of free electricity; and if disguised electricity cannot be carried off to the ground by conductors, the cause is not that it has not propagating power, but that it is restrained by the attraction of the opposite electricity of the inducing and restraining body. To deny to disguised electricity its ordinary properties, is like asserting, that because a stone lies upon the ground it has lost its gravity.

The experiment of *Riess* has proved, beyond all contradiction, that latent electricity acts at a distance as perfectly as though it were not latent. If an electrified body (*a*, Fig. 23) has rendered latent the opposite electricity on a conductor connected with the earth, any point (*c*) in the vicinity is acted on by the electricity of *a* as well as by that of *b*; but since *a* and *b* are charged with opposite kinds of electricity, only the difference of their effect can be observed in *c*.

Fig. 23.

After this contested question might have been considered as settled by the experiment of *Riess*, *Knochenhauer* brought forward new objections. (Pogg. Ann., XLVII, 444.)

Fig. 24.



He excited a cake of resin, and having stretched over it a sheet of tin foil at a given distance, removed from the latter, by a touch of the finger, its free negative electricity. Presenting to this apparatus, represented by a diagram in Fig. 24, two pith balls suspended on linen threads, they do not diverge in the least, the cause of which may be the distance of the pendulum from the sheet of tin foil charged with latent + E.

Knochenhauer concluded, from this experiment, that when two opposite electricities render each other latent, they lose all action at a distance, and stand only in relation to each other; for it could not be supposed that, in case the opposite latent electricities acted at a distance, these effects would perfectly neutralize each other at all points above the tin foil.

Fechner has completely refuted this objection of *Knochenhauer* (Pog. An., LI, 321.) He has shown that, by the aid of the suspended pith balls, no electrical action can be obtained above the induced plate, because they are not sufficiently sensitive to weak charges. If a proof plane be substituted for the balls, and touched for an instant with the finger, it shows, when tested by the pile electrometer, that it is really electrified and similarly with *b b*; a proof that the effect which *a a* has upon *c* exceeds the effect which the latent electricity in *b b* has upon *c*.

Fechner has repeated this experiment, not only in the above described manner, but varied in a great many ways, and always with the same result. It will not be necessary to describe all these different forms of experiment, since, in speaking of the researches of *Faraday* on electrical induction, we shall have to return to some points of *Fechner's* investigation.

At the conclusion of the report on these experiments *Fechner* says:

"From the preceding experiments we are amply justified in considering the attracting and repelling effects of the inducing, and of the so-called latent, electricity, from the same point of view, namely, as free electricity. Electricity, in becoming latent, is invested with no new properties. If its attraction and repulsion be no longer perceptible, this is explained by the fact that they are counterbalanced or overpowered by the opposite effects of the inducing electricity, &c."

Petrina has attempted again to cast doubt upon the correct views of *Fechner*, that tension electricity acts through uninsulated conductors, (Pogg. Ann., LXI, 116,) without, however, being able to advance anything decisive. According to his view, the electricity which *Fechner* found in the electrical "shadow" of the upper metal plate, was caused by the curved surface of the cylindrical space above the upper plate becoming electrified by induction, and the inductive action spreading thence inward.

Petrina has neither established this strange idea nor followed out

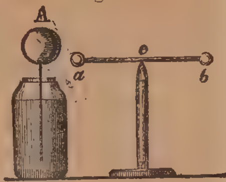
the consequences arising from it. It remains obscure, precisely as he conceived it.

That the electricity of a powerful electrical machine can exercise no perceptible inductive action through a partition wall and closed door of a chamber, should certainly not surprise us, and can be of no value as an argument against the view held by *Fechner*.

In the course of the memoir alluded to above, experiments are described which *Fechner* made to discover how electricity is distributed over an insulated and induced body. The essential results of these experiments are as follows:

A small Leyden jar, provided with a metal ball A (fig. 25) 3 inches in diameter, was charged with + E and insulated. The ball was placed opposite an insulated brass conductor *a c b*. This conductor was cylindrical, 5.2 lines in diameter, with spherical knobs 8.3 lines in diameter at the ends, and 16 inches long. *a* and A were placed 2 inches apart.

Fig. 25.



When the conductor was touched at *a* by the finger, a proof-plane constantly indicated negative electricity, to whatever part of the conductor it might be applied; even at *b* negative electricity was found, the intensity, however, increasing towards *a*. Even from the finger or hand touching the conductor, — E was obtained by the proof-plane.

On the removal of the hand, so that the conductor *a b* became again insulated, the greater part towards *b* indicated *positive*, the less part, towards *a*, *negative* electricity.

This result at first appears surprising, but it can be explained readily by the following consideration:

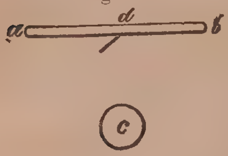
When the conductor is touched at *a*, — E, attracted by A, is accumulated upon the hand, and, of course, acts repulsively upon the — E in *a*. The repulsive action of the — E of the hand, and the attractive action of the + E of the ball A, upon the — E present in *a*, are in equilibrio; but if the — E upon the hand be removed, more — E can accumulate in *a*, a part of the neutral E of *a b* is then decomposed, the — E flows to *a*, while towards *b* is collected the + E repelled by A.

If, on the contrary, the conductor be touched at *b*, — E is indicated throughout its entire length, increasing from *b* toward *a*, being, however, very feeble at *b*; on the removal of the finger, the whole conductor becomes negative, increasing from *b* to *a* as might have been predicted.

The arrangement which electricity must assume upon a conductor exposed to inductive influence, is reduced by *Poisson* to pure mathematical determinations, which are based solely upon the known laws of the attraction and repulsion of electricity. The practical application of theprinciple, however, involves, in many cases, great difficulties; for the composition and decomposition of the actions are to be considered from an infinite number of points. By general consideration, evidently very little can be accomplished in a field where the obtaining of results is too difficult even for the calculus. In such cases it is necessary to seek instruction from experiment.

If electricity be induced upon an insulated conductor, we find, as a general rule, that the electricity dissimilar to that of the inducing body approaches as near as possible to it, and the similar removes as far as possible from it. This rule, however, even if we regard it only as a general guide, leaves much that is undetermined.

Fig. 26.



Let an insulated disk *a b* (fig. 26) be exposed to the inductive action of an electrified sphere *c*. How will the two electricities be distributed on *a b?* Are the edges *a b*, or the middle of the back *d*, to be regarded as the most remote parts of the disk? If *c* be positive, is positive electricity to be expected at *d?*

Fechner has made a series of experiments in answer to these questions. The attracted —E is collected in the greatest quantity at the middle of the front surface, and decreases towards the edges; the repelled +E is found on the back, and its intensity, which is but slight in the middle, at *d* increases towards the edges. The repelled +E embraces the edge, so that it is found at the edge even on the front face; the line of indifference between the +E and —E is on the front, and approaches the middle the closer the sphere is brought to the disk.

Fechner has made similar experiments with rods and strips of metal.

[§ 18 is omitted because it is occupied with the refutation of the views of Knochenhauer, which have never been generally adopted, and which are sufficiently disproved in other parts of this report.]

§ 19. EXPERIMENTAL PROOF THAT THE QUANTITY OF LATENT ELECTRICITY IS IN THE INVERSE PROPORTION TO THE SQUARE OF THE DISTANCE FROM THE INDUCING BODY. In order to set aside definitely the objections of *Knochenhauer*, I have myself made a series of experiments on the law, according to which the strength of the induction decreases when the distance between the bodies acting on each other increases.

The method of observation was essentially the same as that employed by *Knochenhauer*, except that I substituted a straw electrometer, with a graduated arc, for the torsion balance. I had first to find the proportion of the increase of charge to the increase of divergence of the leaves of the electrometer, in order to determine subsequently from the divergences the magnitude of the electrical force which produced them. This was accomplished in the following manner:

A large Leyden jar, having about two square feet of interior coating, was charged with positive electricity: the knob of the jar might be considered as a tolerably constant source of electricity, from which the same small quantity could always be taken and conveyed to the electrometer. This transfer was made by means of a brass knob of about three lines in diameter, insulated by a sealing wax handle of sufficient length. This small knob was brought into contact with the knob of the Leyden jar, and thus charged with a certain quantity of electricity, which we will designate by 1. This quantity 1 was then transferred to the electrometer by touching its plate with the charged knob; the pendulum diverged, and the amount of the divergence was noted.

The small knob was again brought into contact with the knob of

the jar, and the same quantity of electricity transferred to the electrometer, whose divergence thus received a corresponding increase. In this manner the charge of the electrometer was constantly increased, and the corresponding divergence of the pendulum observed.

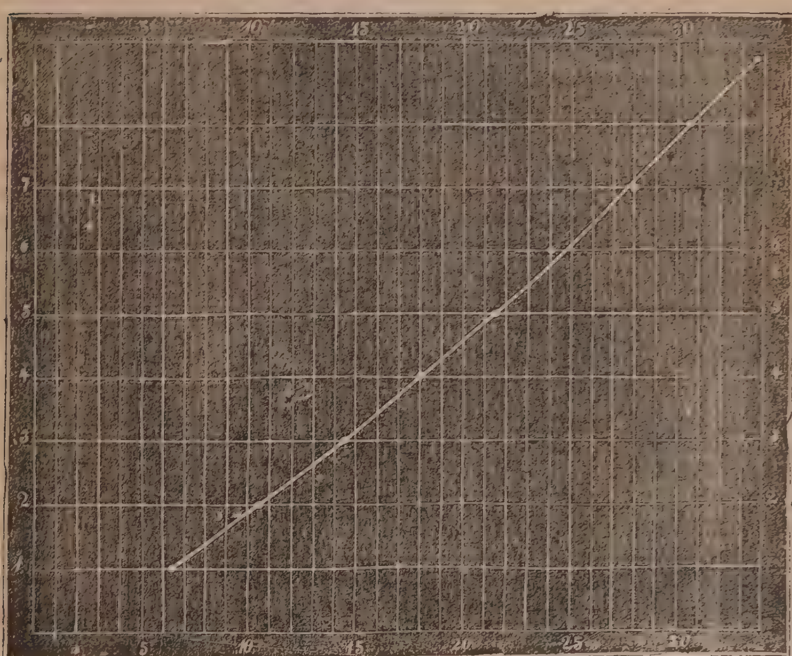
These charges were continued to 7, 8, or 9; the electrometer was then discharged and the same process repeated.

That, during the whole period of the experiment, the strength of the electrical charge of the jar did not diminish perceptibly, is shown by the numbers of the following table, which contains the results of 8 experimental series:

E	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*	Mean.
	°	°	°	°	°	°	°	°	°
1	6	7	7	7	7	6	5.5	6	6.4
2	10	11	11	9	11	10	10	11	10.3
3	15	15	15	15	14.5	16	14	15	14.6
4	18.5	18	19	18	18	19	17.5	19	18
5	22	22	22	21	21.5	22	21.5	22	21.4
6	24.5	25	25	24	24.5	--------	23	23	24
7	28	28	28	27	27	--------	28.5	28.5	28
8	--------	30	32	30	30	--------	31 5	31	30.7
9	--------	--------	--------	--------	--------	--------	33.5	34	33.7

The first vertical column contains the quantities of electricity transferred to the electrometer; each of the following vertical columns contains the corresponding divergences as determined by eight consecutive series of experiments; the last column contains the means of the divergences found for each quantity of electricity.

Fig. 30.



Instead of expressing the connexion between the quantity of electricity with which the electrometer is charged, and the divergence of the pendulum, by means of a complicated formula, I have attempted to render it apparent by graphic representation. In fig. 30, the ordinates represent the quantities of electricity, the abscissas the divergences, and the marked points are those which correspond to the mean divergences belonging to the different quantities of electricity marked on the sides of the figure.

These points admit of being connected by a quite regular curve, as shown in the figure, representing the relation between the quantity of electricity and the divergence, the points corresponding to 6 and 7 only lying a little outside of the curve.

The readings, from which these results were taken, were indeed exact only to a half degree; a greater nicety in reading the single observations is not necessary, since the results (from various causes) are uncertain beyond one half degree, and the separate readings for the same quantity of electricity often differed as much as two degrees. *Knochenhauer*, indeed, gives single minutes in his observations, although the uncertainty of the observation amounts to several degrees; how he could read to single minutes with an instrument so small as his, (44,) it is difficult to conceive; if, however, the instrument actually admitted of so accurate a reading, it was still unnecessary, because the pointing of the needle is not determinable with the same degree of accuracy. In such cases greater accuracy should not be affected than is actually to be obtained under the circumstances.

After the straw electrometer had been tested in the above described manner, I proceeded to the different experiments, which were arranged in the following manner:

A hollow brass ball, two inches in diameter, was suspended by a well insulating silk string. Directly under it stood the electrometer, upon a plate whose support could be slipped up or down and fastened at any desired position. The brass plate of the electrometer was 18 lines in diameter.

Fig. 31.

On the rod which bore the plate of the stand three marks were made, at distances of 3 inches from each other. When the lowest of these marks was at the upper end of the hollow leg, the plate of the electrometer was 3 inches from the middle point of the ball; and this distance amounted to 6 and 9 inches when the second and third of the marks were similarly placed. Three inches being taken for unity, the electrometer plate could be shifted to the respective distances, 1, 2, and 3.

When the plate of the electrometer stood at the distance 3 from the ball, it was touched with the finger, and the ball a charged by bringing a small Leyden jar into contact with it.

As soon as the ball was charged in this manner, the jar was quickly put aside.

The electricity on a had then rendered latent a definite quantity of the opposite E on b, which

came measurable by removing the finger from b, and, at the same time, pushing aside a with the hand.—A divergence of 6° was indicated.

The plate of the stand was then raised 3 inches higher, so that the distance between b and the centre of a was equal to 2, or 6 inches, and the experiment repeated, in the same manner, by applying the same jar with its charge.—A divergence of 12° was now indicated.

The same experiment, repeated for the distance 1, gave the divergence, 30°.5.

The electrometer was then placed at the position 2, 3, 2, 1, 2, 3, &c., in succession, and the same experiment made. The result of the observations are collected in the following table:

Distance.	Divergence.	Mean.
1	30.5 31.5 30 31 30	30.6°
2	12 12 12.5 10 12 11 10.5 11.5 11 11.5	11.4
3	6 6 5.5 6 7 6	6.2

With equal charges of the ball a the mean divergence 30°.6 was obtained at the distance 1; the divergence 11°.4, at the distance 2; and the divergence 6°.2, at the distance 3.

Equal charges of the ball a were obtained by bringing it in contact with the knob of a Leyden jar charged once for all for the whole series of experiments. The charge of the jar was, indeed, somewhat diminished at each contact with the ball, but this diminution was not sensible after the twentieth contact, as the above table shows.

We shall now see how great the changes are which give to our electrometer, the deflections, 30°.6, 11°.4, and 6°.2.

From a consideration of Fig. 30, it follows that the divergence, 30.6 corresponds to the electrical quantity 8 the divergence 11.4 to the quantity 2.25; and 6.2 to 0.95. The quantity of electricity which the ball a renders latent on b, is, therefore

At the distance 1, equal to 8.00.
" " 2 " 2.25.
" " 3 " 0.95.

These numbers are very nearly in the ratio of 1 : 4 : 9; or inversely as the square of the distance. At the distance of 1, the reading of the divergence is rather too small, which can be easily explained. For such heavy changes of the electrometer, causing a deflection of upwards of 30 degrees, the pendulum sinks more suddenly by reason of the more rapid loss; thus, when the reading is taken, the original divergence has already slightly diminished.

A similar series in which the alternation was only between the single and double distance, (4 inches being the unity of distance,) gave the following result:

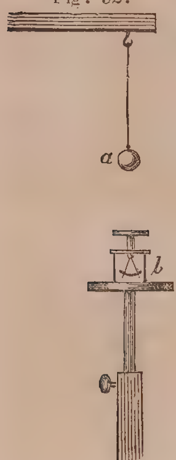
Distance.	Divergence.				Mean.
1	26	24	24.5	24	24.6
2	9	9	8.5	9	8.87

The divergence 24.6 and 8.87 correspond to the quantities of electricity, 6 and 1 6, which likewise are very nearly in the proportion of 4 to 1; thus again at a double distance, we have one-fourth the quantity of latent electricity.

I should think that these experiments were sufficient to place beyond doubt, the principle that, *the quantity of electricity which is rendered latent on an uninsulated conductor by a neighboring insulated electrified body, is in the inverse proportion of the square of the distance of the two bodies*, provided that their dimension and the distance, are such that the electrical force can be considered as concentrated in their centres of gravity, without considerable error.

In the experiments of *Knochenhauer*, the distance between the inducing body and that upon which the opposite electricity is rendered latent, was *much* less than in mine; his least distance was 3 lines, mine was 3 inches. This fact gives rise to the supposition that in his experiments, electricity may have gone over. To find out whether this could really have happened, I made the distance between the ball *a* and the electrometer plate, 3 lines in the clear, and then placed the electrometer so that the distance of the plate from the centre of the ball was double as great as in the first position. In this case also at a double distance, the effect was about one-fourth, consequently, no electricity had passed from the ball to the plate.

Fig. 32.



But the ball was quite large, and the plate, a portion of an indefinitely large sphere; the ball *a*, moreover, was varnished; circumstances far less favorable to the passage of electricity than in the arrangement of *Knochenhauer*.

I now exchanged the ball *a* for another not varnished, and only 8 lines in diameter; the plate of the electrometer was removed and replaced by a ball about 4 lines in diameter. When the distance between the balls amounted to 12 lines or 18 lines between their centres; on repeating the experiment in the above described manner, I obtained from a charge, which of course had to be quite weak, a divergence of 8 to 10 degrees; but when the electrometer was brought so near, that the distance in the clear amounted to only 3 lines, the distance of the center being then only half as great as in the first position, for equal charges of the small ball *a*, there was not a divergence of the pendulum anything near four times as great as before, but a divergence of only 10°.

Evidently electricity had gone over between the balls, hence the charge of the upper ball, as well as the quantity of latent electricity on the lower one, was considerably diminished.

There is not the least doubt, that this acted injuriously in the experiments of *Knochenhauer*, and made his results perfectly valueless.

[§ 20 is omitted for reasons mentioned under § 18]

§ 21. FARADAY'S RESEARCHES ON LATENT ELECTRICITY.—*Faraday* also has made the induction of electricity a subject of research. In his

eleventh series of *Experimental researches in Electricity*, (Pog, An. XLVI, 1) he endeavors to prove that induction is not the consequence of electrical action at a distance, but is effected by the inducing body through the medium of the intervening material particles.

In order to prove that induction is the result of an action progressing from particle to particle of the separating insulator, *Faraday* seeks to prove—

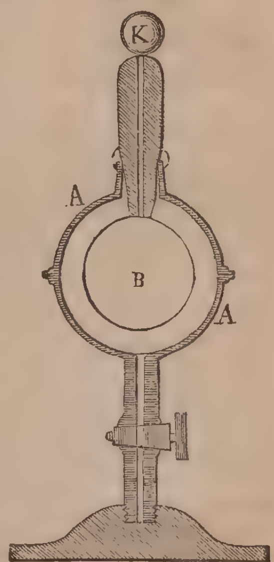
1st. That at the same distance of the inducing body and that on which electricity is excited and rendered latent by induction, the force of the induction is dependent upon the nature of the intervening insulator; that the induction under otherwise like conditions is not the same through different insulators; that therefore to each insulator belongs a peculiar specific inductive capacity.

2d. That induction can take place in curved lines.

§ 22. Specific inductive capacity.—We will first consider the specific inductive capacity of insulators.

In fig. 35, A represents a hollow metallic sphere, standing on a metallic support. In an opening at the top a cylinder of shellac is fastened tightly, through the middle of which a wire passes, having at its upper end a small metallic knob K, and at the lower the metallic ball B. The diameter of the sphere A is about 8.5 centimetres, ($3\frac{1}{2}$ inches,) that of the ball B is 6 centimetres, ($2\frac{1}{3}$ inches). The sphere A consists of two pieces similar to the Magdeburg hemispheres, and so arranged that the upper half can be removed together with the shellac cylinder and the balls K and B.

Fig. 35.



Faraday, in his experiments, used two perfectly similar instruments of this kind, which he termed an *inductive apparatus*.

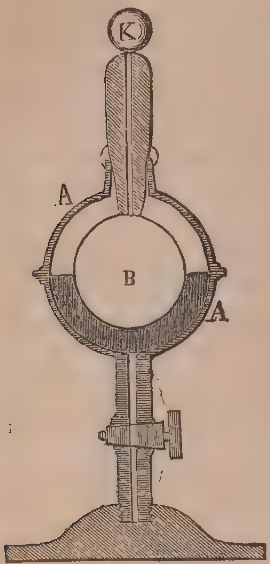
Such an apparatus can be charged like a Leyden jar, by bringing K into contact with a source of electricity, and connecting A with the ground. Thus, B represents the inner coating, A the outer, and the stratum of air between takes the place of the glass.

An apparatus of this kind, which I shall indicate by I, was charged as above shown. It is evident, as in the case of the inner coating of a Leyden jar, that there must be an excess of free electricity on B and K, the tension of which was measured by Coulomb's torsion balance. In order to maintain the centre of the two balls of the balance at an angular distance of 30°, a torsion of the thread of 250° was necessary.

The knob K of the apparatus I was then touched by the knob K of a perfectly similar apparatus II, while its exterior sphere was in connexion with the earth. The charge, which had been previously communicated to apparatus I alone, was now divided between the two. After this division, the force of the free electricity of the interior was determined for each; the first corresponded to a torsion of 124°, the other to a torsion of 122° of the balance, in order to maintain the balls

in both cases at the angular distance of 30°. Thus, after the division, the free electricity of the inner coating was nearly equal in the two instruments, and as might have been predicted, was half as great on each as on I before the division.

Fig. 36.



In apparatus II, half of the air was now replaced by another dielectrical medium, (*Faraday* thus names the medium through which electrical induction takes place). Shellac was first tried. The upper half of the apparatus II was removed, in the under part of the sphere A, a hemispherical cup of shellac was placed, and the upper half returned again to its place, so that the intervening space between the lower half of the two spheres was filled, as shown in fig. 36.

Apparatus I, which remained unchanged as in the first experiment, was charged again, in the same manner as before, and the free electricity of the inner coating, measured by the torsion balance. Thus, the result was by

Apparatus I............................290°.

The charge was now divided between I and II, and after the division the result was,

Apparatus I............................114°,
Apparatus II...........................113°.

Here, also, the free electricity of the interior coating of the two instruments is very nearly equal after the division, but it is far less than the half of the free electricity of apparatus I before the division; hence, it follows, that apparatus II had received more than half the electricity of I, but without the free electricity on II being more than on I, and consequently *Faraday* concludes that a more powerful induction takes place through shellac. If we represent the quantity of free electricity of the interior coating of I, before the division, by 290°, then the whole quantity of its electricity will be n 200; after the division there remained only n 114; hence there has been given to apparatus II

$$n\,(290 - 114) = n\,176.$$

In *Faraday's* opinion another relation takes place between the latent and free electricity; the free electricity is 113, the latent is n'. 113; we have, consequently,

$$n'\ 113 = n\ 176,$$

hence

$$n' = n\ \tfrac{176}{113} = n\ 1.55.$$

Accordingly, an inductive force 1.55 times greater takes place through shellac than through air; or, as *Faraday* expresses it, *shellac has* 1.55 *times greater specific inductive capacity than air.*

By similar experiments *Faraday* found the specific inductive capacity of sulphur to be 2.24 times as great as that of air.

For the various gases *Faraday* found their inductive capacity equal to that of air. In order to introduce the different gases into the ap-

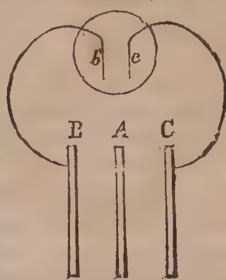
paratus the support was perforated and furnished with a stop-cock; it could be screwed to an air pump, a vacuum made, and any other gas introduced.

Rarifying and heating the air produced no change in its specific inductive capacity.

Faraday made further experiments for the purpose of establishing his views on this subject.

Let A, fig. 37, be an insulated metallic plate placed between two other metallic plates, B and C, insulated in like manner, B and C being each $\frac{5}{4}$ inch distant from A. With C a wire was connected which termited in the gold leaf *c*, and in like manner a wire fastened to B terminated in the leaf *b*. The two gold leaves hung in a glass jar two inches apart. B and C were then connected with the ground and a weak positive charge given to the plate A, by means of which B and C were charged with — E. The connection of B and C with the earth was then cut off, so that these two plates were again insulated—the gold leaves *b* and *c* remained suspended parallel to each other as before.

Fig. 37.



A shellac plate, $\frac{3}{4}$ inch thick and 4 inches square, suspended by a clean thread of white silk, after being carefully deprived of all charge, was brought between the plates A and B. The electric relations of the three plates were at once altered, and attraction was produced between the gold leaves. On the removal of the shellac this attraction again disappeared. The shellac having been then examined by a sensitive *Coulomb's* electrometer, indicated no charge.

In this *Faraday* found a further confirmation of his views, and he explained the result as follows: As soon as the shellac plate is introduced between A and B a strong charge of negative electricity takes place on B—it repels the positive, which is thus diffused towards *b;* but, since A acts more powerfully on B than before, negative electricity on C must be set free; thus *c* will contain free — E, while free +E is on *b;* hence the attraction of the leaves.

How *Faraday* has proved that this electricity is set free on *b* and *c*, as it must be according to his theory, does not appear in his memoir.

Faraday's experiments are perfectly correct, but it appears to me that he has erroneously interpreted these experiments and drawn a conclusion from them in which he is not justified. The grounds for this assertion are as follows:

If an insulated electrified body A is placed opposite a second conductor B, which is in communication with the ground, a definite quantity of electricity will be rendered latent on B. A part of the E on A is then disguised by the opposite kind on B, and a part is free. If shellac is now placed between A and B, more electricity is disguised on A, and there is less free than before; this is the fact which is exhibited by the experiments of *Faraday* with the inductive apparatus. He further asserts, however, that a stronger induction takes place through the shellac, but this he has not proved by experiment. To be justified in this assertion he should have shown, that with equal charges

on A, more electricity will be induced on B when shellac is placed between them, than when air is the intervening insulator. The experiment indicated in fig. 37 tends just as little as that with the inductive apparatus to lead to the above explanation.

The following experiment is well adapted to bring the question to a decision:

Fig. 38.

Under an insulated and electrified metallic ball *a*, 1 or 2 inches in diameter, fig. 38, place a gold leaf or straw electrometer at such a distance that a considerable divergence may be obtained. If the ball *a* be charged with +E, then —E will be induced in the plate of the electrometer *b*, and the +E will be repelled by *a* into the pendulum; hence its divergence.

Now put a plate of shellac between *a* and *b*.

If *Faraday's* view be correct, a stronger induction must take place through the shellac than before; more —E should be induced in the electrometer plate, and thus more + E should be forced into the pendulum, and its divergence should increase.

But the experiment shows that the divergence of the pendulum decreases as soon as the shellac plate is introduced. Hence, most decidedly, a stronger induction does not take place through shellac than through air.

If a greater quantity of the electricity on *a* is dis uised after the introduction of the shellac than before, it is evidently caused by a mutual action between *a* and the shellac plate; but by no means because a stronger induction takes place through the shellac.

Knochenhauer has instituted an experiment similar to this, but he has entirely mistaken its signification.

Instead of an electrometer with two suspended leaves, he used a pile electrometer, (Pogg. Ann. LI, 126.) A weak *positive* charge was imparted to the conductor *a* (which, in his experiments, was a metallic plate instead of a ball, producing the same result, however) at the same time the plate of the electrometer was touched; — E was thus induced in this plate. A plate of shellac was then placed between the electrometer plate and the electrified conductor *a*, when a movement of the gold leaf took place, and *Knochenhauer* asserted "that simultaneously with the introduction of the shellac plate the leaf of the electrometer indicated free positive electricity, so that now, on the lower disk, more negative electricity was disguised." This was in perfect harmony with *Faraday's* view; but it is in direct opposition to the results of the experiments with the straw electrometer instituted by me. According to my experiments, I am obliged to suppose that the movement of the gold leaf indicated free negative electricity.

It might be supposed that *Knochenhauer* was deceived as to the pole of his gold leaf electrometer, so that he confounded a negative with a positive indication.

In order to come at this definitely, I repeated *Knochenhauer's* experiment. The ball *a* was charged with + E, and when a shellac plate was introduced between *a* and the electrometer plate, the gold

leaf moved towards the positive pole of the instrument; that is, towards that one which it strikes when a rubbed stick of rosin is approached from above; the gold leaf then received free — E by inserting the shellac plate.

If *Knochenhauer's* view were correct, the gold leaf, on the introduction of the shellac plate, (a being positive,) should move toward the side which is approached when a glass rod rubbed with silk is brought over the electrometer. But the proximity of rubbed glass produces a result opposite to that effected by the presence of the shellac plate. Thus the error of *Knochenhauer* with reference to the nature of the indication is proved.

Faraday's opinion that a stronger induction is effected through shellac than through air, is hence *decidedly* wrong. The experiments made with the straw electrometer, as well as with the pile electrometer, directly contradict this view.

But how are all these phenomena to be explained? I beg leave to offer a few hints, which, perhaps, will serve to point out the way that may lead to a definitive decision of the question.

If we introduce between the electrified ball a, fig. 38, and the straw electrometer an uninsulated conductor, the pendulum will collapse. According to known laws, nothing else could be expected.

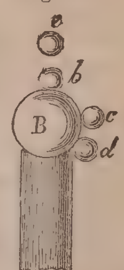
If we introduce an insulated metallic disk between a and the electrometer, a considerable diminution of the divergence will occur, but the pendulum will not completely collapse. This is in consequence of an inductive action which a exerts upon the intervening insulated metallic plate.

If we introduce a shellac plate between a and the electrometer, a similar diminution of the divergence will take place, but yet not so much as in presence of the insulated metallic plate. This seems to indicate that the electrified body a causes an induction even in the shellac, though not to such an extent as in a good conductor. In fact, we know that shellac, though a very bad conductor, is not an absolute insulator.

Knochenhauer also seems to hint at something similar in the memoir cited. At any rate, this matter needs further investigation; but so much is certain, that a more powerful induction does not take place through solid insulation than through air, as *Faraday* maintains.

§ 23. Induction in curved lines. We proceed now to the consideration of Faraday's proof of induction in curved lines.

Fig. 39.



A cylinder of shellac 0.9 of an inch in diameter, which can be placed upright, and has a cavity at the top, is electrified by friction, and a brass ball 1 inch in diameter laid in the cavity or cap. If now an insulated proof ball be brought into the positions indicated by d, c, b, and e, touched for an instant, and then tried whether it have any electrical charge, and of what kind, it is found that the carrier will receive a positive charge at d and c, as well as at b and e.

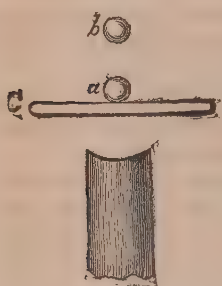
The result of this experiment has nothing in it at all remarkable, it might have been predicted. The ball B is electrified positively by induction; the — E of the shellac cylinder

and the induced + E of the ball B act simultaneously upon the carrier wherever it may be, the effect of the cylinder preponderates, and hence the carrier must be charged with induced + E at *b* as well as at *e*.

This case is perfectly analogous to that already mentioned in § 17. *Faraday* explains the matter thus: The proof ball is electrified at *b* as well as at *e* by induction; but since it is impossible to connect by a straight line the shellac cylinder with either *b* or *e*, the induction must take place around B through the air, consequently there must be induction in curved lines. To arrive at this conclusion, *Faraday* must naturally suppose that no inductive action can take place through a conductor.

That no induction can take place through metal, *Faraday* believes he can prove.

Fig. 40.



A metallic plate, C, fig. 40, was held above the shellac cylinder, and touched for a moment, so that it should be charged by induction with + E. A proof plane, or a small proof ball, was now held at *a*, close to the middle of the plate, and touched for a moment, when it gave no indication of a charge; hence *Faraday* concluded, that the electricity of the shellac cylinder cannot act inductively through the metal plate; but when the proof ball was raised to about the distance of *b*, it received a positive charge, which, according to his view, showed that induction could take place in curved lines around the plate upon point *b*.

Fechner has described the same experiment in a somewhat different form, in the memoir already cited, (Pog. Ann. LI, 321.) He has shown that the phenomena, as *Faraday* describes them, are necessary consequences of the known laws of induction.

Fechner says: "That the maximum of the effect is seen at some distance from the upper plate,* is not at all surprising. For all points of the upper plate, the influence of the negative electricity which it contained, must be in exact equilibrium with that of the positive electricity of the lower plate; otherwise, more or less electricity would be decomposed in the upper plate, and accumulate more than the case shows. By elevating the proof plane above the upper plate, its distance from the points of the upper plate increases in another proportion, than from those of the lower plate; hence the influence of the latter begins to predominate. Yet the increase of the action with the elevation of the proof plane cannot go beyond a certain maximum, because at a greater distance the action of each plate separately would disappear."

These phenomena, consequently, are not a proof of induction in curved lines; and, in general, it may be asserted that *Faraday* has not presented a tenable proof of his hypothesis, namely, that induction takes place through the contiguous particles of the intervening insulator.

§ 24. FARADAY'S THEORY OF INDUCTION.—*Faraday* endeavors, in the

* *Fechner* used (instead of a shellac cylinder) an insulated and positively electrified metallic plate, which he termed the lower plate.

12th and 13th series of his *Experimental researches*, (Pog. Ann. XLVII, XLVIII,) to support his theory of induction by a consideration of the different forms of electric discharge. He classifies the different kinds of discharge by dividing them into *conductive discharge*, *electrolytic discharge*, *disruptive discharge*, (sparks, brushes, &c.,) and *convective discharge*.

In considering the conductive discharge, *Faraday* endeavors to prove that the difference between insulators and conductors is only quantitative—a truth which no one, to my knowledge, has disputed.

The *electrolytic discharge*, says *Faraday*, is preceded by an inductive action through the electrolyte; the inductive state being, in fact, a necessary preliminary to discharge, decomposition is preceded by the state of polarization or tension of the particles of the fluid to be decomposed. To this also nothing is to be objected.

For the *disruptive discharge*, *Faraday*, in like manner, endeavors to prove that the particles of the dielectric through which the discharge takes place, whether in the form of a spark or brush, are also in a state of tension or polarization.

Though we cannot get a clear conception of such a state of tension or polarization of the particles of air which precedes the spark or brush discharge, yet the existence of such a state is not in the least doubtful, neither is its admission at all opposed to the heretofore acknowledged electrical theories. But *Faraday* goes further: he regards this polarized state as a proof that the electric inductive effect which takes place through the air, or the dielectric substituted for it, is *produced by means of their polarized state*. For the correctness of this view *Faraday* has yet to furnish the proof.

With the design of establishing his theory of induction, *Faraday* made many experiments on sparks and brushes, which, though they are not very important to the present subject, yet are interesting, and, as valuable facts, will be described in another place.

Since conduction and insulation have only a quantitative difference, *Faraday* thinks that even in the better conducting fluids a convective discharge might take place, if only a sufficient quantity of electricity were present. The following experiment would seem to support this opinion:

Two platinum wires, forming the poles of a powerful voltaic battery, were fused hermetically, near to each other and side by side, in a strong glass tube containing distilled water, having a few filaments in it. When the bubbles at the electrodes, in consequence of the increased pressure caused by the continuous development of gas, had become so small that they produced only a weak ascending current, it could be noticed that the filaments were attracted and repelled between the two wires, as though between two oppositely charged surfaces in air or oil of turpentine. They moved so rapidly that they displaced and disturbed the bubbles and the currents formed by them. *Faraday* supposed it could hardly be doubted that, under similar circumstances, with a large quantity of electricity, of sufficient tension, convective currents might be formed. The attractions and repulsions of the filaments were in fact the elements of such currents; hence, water, although it is almost an infinitely better conductor than air or oil of turpentine, is a medium in which similar currents can take place.

Faraday's theory does not pretend to decide upon the consequences of a vacuum. According to his view, electrical phenomena, such as induction, conduction, and insulation, depend on, and are produced by, the influence of *contiguous* particles of matter, the *nearest* particle being considered as the *contiguous* one; he assumes further, that these particles become polarized, and that they act at a distance only by acting on the *contiguous* and intermediate particles.

Suppose a vacuum to be in the line of induction; it does not follow from the theory, says *Faraday*, that the particles on the opposite sides of such a vacuum cannot act on each other. Suppose it possible for a positively electrified particle to exist in the centre of a vacuum one inch in diameter; nothing in my theory prevents the particle from acting, at the distance of half an inch, on all the particles forming the surface of the sphere with a force according to the known law of the square of the distance.

Here, however, *Faraday* again assumes the action at a distance.

In the fourteenth series of Experimental Researches, (Pog. Ann. Sup., vol. of 1842,) *Faraday* collected his views on the nature of electrical force, and particularly on the state of tension accompanying induction. I quote this summary literally:

"1669. The theory (*Faraday's*) assumes that all the *particles*, whether of insulating or conducting matter, are, as wholes, conductors.

"1670. That not being polar in their normal state, they can become so by the influence of neighboring charged particles, the polar state being developed at the instant, exactly as in an insulated conducting *mass* consisting of many particles.

"1671. That the particles when polarized are in a forced state, and tend to return to their normal or natural condition.

"1672. That being as wholes conductors, they can readily be charged, either *bodily* or *polarly*.

"1673. That particles which, being contiguous, are also in the line of inductive action, can communicate or transfer their polar forces one to another *more or less* readily.

"1674. That those doing so less readily require the polar force to be raised to a higher degree before this transference or communication takes place.

"1675. That the *ready* communication of forces between contiguous particles constitutes *conduction*, and the *difficult* communication *insulation;* conductors and insulators being bodies whose particles naturally possess the property of communicating their respective forces easily or with difficulty; having these differences just as they have differences of any other natural property.

"1676. That ordinary induction is the effect resulting from the action of matter charged with excited or free electricity upon insulating matter, tending to produce in it an equal amount of the contrary state.

"1677. That it [the charged matter] can do this only by polarizing the particles continguous to it, which perform the same office to the next and these again to those beyond; and that thus the action is propagated from the excited body to the next conducting mass, and these render the contrary force evident in consequence of the effect of

communication which supervenes in the conducting mass upon the polarization of the particles of that body, (1675.)

"1678. That, therefore, induction can only take place through or across insulators; that induction is insulation, it being the necessary consequence of the state of the particles and the mode in which the influence of electrical forces is transferred or transmitted through or across such insulating media.

"1679. The particles of an insulating dielectric whilst under induction may be compared to a series of small magnetic needles, or more correctly still to a series of small insulated conductors. If the space round a charged globe were filled with a mixture of an insulated dielectric, as oil of turpentine or air, and small globular conductors, as shot, the latter being at a little distance from each other, so as to be insulated, then these would in their condition and action exactly resemble what I consider to be the condition and action of the particles of the insulating dielectric itself. If the globe were charged these little conductors would all be polar; if the globe were discharged they would all return to their normal state, to be polarized again upon the recharging of the globe. The state developed by induction through such particles on a mass of conducting matter at a distance would be of the contrary kind, and exactly equal in amount to the force in the inductric globe. There would be a lateral diffusion of force, (1224, 1297,) because each polarized sphere would be in an active or tense relation to all those contiguous to it, just as one magnet can affect two or more magnetic needles near it, and these again a still greater number beyond them. Hence would result the production of curved lines of inductive force if the inducteous body in such a mixed dielectric were an uninsulated metallic ball, or other properly shaped mass. Such curved lines are the consequences of the two electric forces arranged as I have assumed them to be; and that the inductive force can be directed in such curved lines is the strongest proof of the presence of the two powers and the polar condition of the dielectric particles.

"1680. I think it is evident, that in the case stated, action at a distance can only result through an action of the contiguous conducting particles. There is no reason why the inductive body should polarize or affect *distant* conductors and leave those *near* it, namely, the particles of the dielectric, unaffected; and everything in the form of fact and experiment with conducting masses or particles of a suitable size contradicts such a supposition."

As a consequence of the above, *Faraday* supposes all bodies to consist, as it were, of small conductors which are separated by an insulating substance; the inductive action of one particle on another, he must also assume, to be precisely like induction between two conductors, as generally supposed; he must then assume *action at a distance* of the ordinary kind between each two particles of the insulator. Since he must assume this at last, and an insulating interval, there is really little reason to set aside the accepted opinions which, though they may have many deficiencies, must be maintained until overwhelming proof establishes not only their insufficiency, but their incorrectness also.

In continuation of the fourteenth series, *Faraday* notices the induc-

tive capacity of crystalline bodies in different directions. According to his idea of specific inductive capacity, it is evidently possible that crystalline bodies have not equal inductive capacity in all directions; that, for instance, rock crystal, or calc spar, might have a greater or less inductive capacity in the direction of their optical axes than perpendicular to them. *Faraday's* experiments leave this question wholly undecided; in most cases exceedingly small differences being indicated, while in others, where greater differences appeared, colored seams in the crystal, cracks and the like, may have had an injurious effect. I do not consider it necessary here to enter more into detail.

Faraday's views on electrical induction must necessarily have forced upon him the question, whether magnetic attraction and repulsion, as heretofore supposed, are to be ascribed to action at a distance, or whether magnetism in a similar manner acts at a distance through the *medium of intervening particles*, analagous to induction in static electricity according to his view.

The experiments which he made for the solution of this question gave invariably negative results, whether he used plates of shellac, sulphur, or copper, as intervening bodies. No sign of the influence of intermediate particles could be obtained.

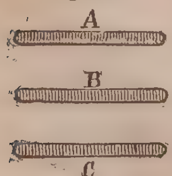
Even if the first experiment did not succeed in showing that magnetism acts at a distance through the medium of intervening particles, it is still conceivable that a magnet might affect all the particles of the non-magnetic bodies surrounding it, and place them in a peculiar state of tension, similar to that of the dielectric, through which induction takes place from one conductor to another; and it is certain that *Faraday*, in his endeavors to discover proofs for such a state, was led to the discovery of the rotation of the plane of polarization by the magnetic poles and galvanic currents as well as to dia-magnetism; discoveries which alone would be sufficient to make his name immortal in the history of science.

§ 25. MUNCK AF ROSENSCHÖLD ON INDUCTION. In the 69th volume of Poggendorf's Annalen, is a memoir by *Munck af Rosenschöld*, in which induction is treated of. In his somewhat extended consideration of the subject, into which he naturally introduces much that is known, he starts with the correct view of induction, which is also defended by Riess and Fechner.

The following constitutes the most important parts of *Rosenchöld's* memoir:

Let the plate A, Fig. 41, be electrified and act inductively on B and C. Let E be the quantity of electricity on A, and it will induce upon B, which communicates with the ground through a fine wire, the quantity of electricity $-mE$. If the plate C be now brought within the "electrical shadow" of B, and connected with the ground, both A and B will act upon this plate. If we indicate by m' the co-efficient of induction which belongs to the distance between B and C, then $m'mE$ will be disguised on C by A, if m'' represents the co-efficient of induction corresponding to the distance between A C; then there will be disguised on C,

Fig. 41.



$$c = m\,m'\,E - m''\,E.$$

The density of the electricity induced on C is always very small; if it were zero we should have

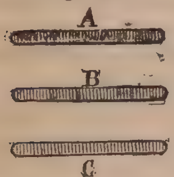
$$m \,.\, m' = m''$$

If this were rigidly true, we should have m^2, m^3, m^4, &c., for the coefficients of induction for the distances 2, 3, 4; m being the coefficient for the distance 1; or, in other words, the distances would be the logarithms of the coefficients of induction.

But the electricity disguised in C is not zero, though it is very feeble. It becomes imperceptible when C is very near B, or even when A is brought very close to B; for a given distance between A and C, the induced electricity becomes a maximum when B is placed exactly in the middle between them.

These relations had been already discovered by *Fechner*, who describes them in his treatise above quoted.

Fig. 42.



Rosenschold now sought to determine in what proportion the quantity of electricity disguised on C varies, when the intermediate plate B is insulated, and is then put in connection with the ground.

The plates A, B, and C, were 6 inches in diameter, the distance from A to C was 9 inches, and B was mid way between them. When B was uninsulated, Rosenschold found that the electricity disguised on C was only $\frac{1}{75}$ of what there was when B remained insulated. In the latter case, that is, when B is insulated, according to *Rosenschold's* experiments, it is quite immaterial whether this plate be present or not.

When the distance from A to C was half as great, the electricity induced on C, B being uninsulated, was only $\frac{1}{235}$ of that which was disguised there when B remained insulated.

A and C having been placed at the distance of 2 feet from each other, the electricity disguised on C was inconsiderable, but on touching B it amounted to more than half of what was observed when B was insulated.

Similar experiments were made with three-inch plates.

When A and C were 9 lines apart, and B was touched, the quantity of electricity disguised on C was $\frac{1}{27}$ of the quantity on it when B was insulated.

As a final result of these experiments, it was found that m'' differed very little from $m\,m'$, as long as the distance of the plates A and C from each other did not exceed from $\frac{1}{4}$ to $\frac{1}{8}$ of their diameter.

With reference to the above ratios $\frac{1}{75}$, $\frac{1}{235}$, $\frac{1}{27}$, it may be remarked that *Rosenschold* has not stated, as he should have done, how the indications of his electrometer used for these measurements, were made properly comparable.

§ 26. Riess on induced electricity and the theory of condensers. The last labors on this subject which we have to mention here, are those of *Riess*, published in the 73d vol. of *Poggendorff's Annalen*, under the title: "*On Influence Electricity and the Theory of Condensers.*" By the name *influence electricity*, *Riess* designates that which is generally

termed *disguised* (*gebundene*) *electricity*, a designation which *Riess* shows, in the historical introduction to his memoir, has contributed much towards establishing erroneous views on the nature of induced electricity.

Lichtenberg first introduced the expression "*bound*" electricity into science. He speaks of *bound*, *latent*, or *dead* electricity, in contradistinction to *free* or *sensible;* he distinguishes from the ordinary electrical condition another, in which electricity, although present, is inactive, dead, latent, perfectly analogous to latent heat.—(*Erxleben's* Elements of Physics, 3d edition, with additions by *Lichtenberg*, 1784, page 499.)

This has produced very injurious consequences to science, and has given occasion to the strange ideas on the existence of induced or disguised electricity, which, obstinately defended as we have already seen, cannot be corrected without much trouble. However, we can now regard the opinion that latent electricity has entirely peculiar properties, as finally refuted. [See note at the commencement of this section.]

Biot presents the theory of condensers and the Leyden jar somewhat in this manner: If to an insulated metallic plate the quantity of electricity 1 be communicated, this will disguise, in a neighboring metalic plate connected with the earth, a quantity of electricity m, which, reacting upon the first plate, will disguise in it the quantity m^2, so that there is remaining only the quantity $1 - m^2$ as free electricity. If E be the greatest quantity of electricity which the insulated plate can receive separately, it will continue to receive more in the presence of the condenser plate, until its *free* electricity amounts to E. Represent by A the whole quantity which the insulated plate is now capable of receiving, and we will have

$$(1 - \mathrm{m}^2)\,\mathrm{A} = \mathrm{E}, \text{ hence } \frac{\mathrm{A}}{\mathrm{E}} = \frac{1}{1 - m^2}.$$

This fraction indicates the ratio of the quantities of electricity which the insulated plate can receive, standing first alone and then in the presence of the condenser; it expresses, consequently, the condensing power of the apparatus.

This formula is perfectly admissible in so far as it serves only for illustrating the action of the condenser, but it must be regarded as misused when it is employed for computing the condensing power of the apparatus. *Riess* has proved that the coefficient of accumulation of the condenser is not a definite quantity, dependent only upon the distance of the plates, but that it varies with the form and magnitude of the condenser plate, with the position of the conducting wire of the plate, with the point in which the collector receives the electricity from the source of excitation, &c. In short, *Riess* has shown that the coefficient of acumulation is a quantity which varies in the same instrument from one experiment to another; that consequently the above formula cannot be used for computing the condensing power of the apparatus.

I beg leave to make a few remarks on the manner in which *Riess*

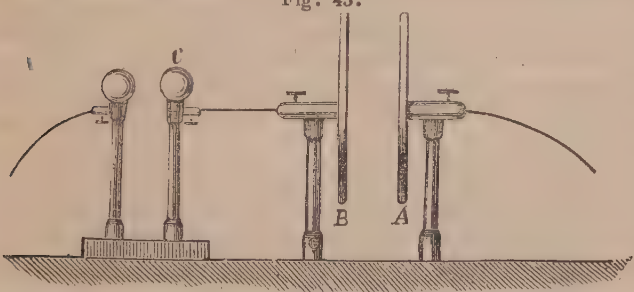
speaks in relation to this formula. He expresses himself strongly against it, so that one would get the notion that the entire conception which *Biot* presented of the action of the condenser was not only faulty, but fundamentally wrong. *Riess* justly censures the *misuse* which has been made of the formula in computing the condensing power of the apparatus, and shows incontestably, by experiment, that such an application is not admissible; but in the introductory consideration he expresses himself in a manner which would lead one to believe he desired to prove far more against the formula than is in fact his purpose, and from this cause it is somewhat difficult to understand his memoir. It appears subsequently, however, that in his opposition to the formula not so much is intended as would seem at first to be the case, and it becomes clear to the reader after a while, that he only censures the misuse of the formula, which in the end rests upon the same notion of the action of the condenser which he himself developes. The discussion is in part a strife about words.

We pass now to the experiments which *Riess* instituted to discover and explain the mode of action of the condenser, and the circumstances which influence the capacity of the instrument for condensing.

Two plane brass disks, 87.6 lines in diameter, $\frac{17}{124}$ of a line thick, with rounded edges, were in the middle of one side provided with cylindrical handles, 15 lines long and 11 lines thick. These handles are perforated in their axes so that a conducting wire may be fastened in them by means of a clamp screw. At right angles to their axes they have a cavity in which a glass rod, coated with shellac, somewhat over eight inches long is cemented. These rods bearing the disks stand vertically on a horizontal base as shown in fig. 43.

The induced plate A or condenser can be laid on its back by means of a hinge. The inducing disk B, known as the collector is placed on a slide so that it can be brought near to or removed from A at will, and the distance measured accurately.

Fig. 43.



The condenser A, when in use, was connected by a metallic wire with the gas pipes of the house, as a discharging train.

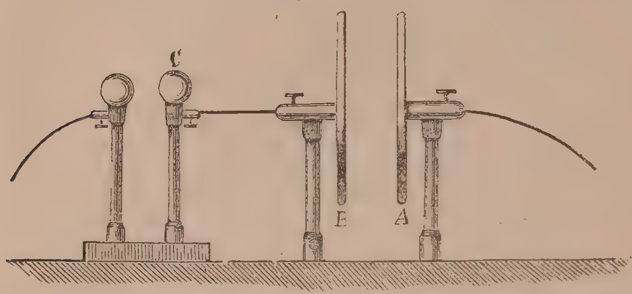
The collector B was connected by a metallic wire with one knob of a spark micrometer, fig. 50, the other knob of which communicated with the gas pipes of the house.

A being turned down, so that B stood alone, the latter was then electrified by contact with the knob of a Leyden jar. The free electricity distributed itself over the whole insulated system, that is, over the plate B, and the knob of the spark micrometer connected with it. The striking distance of the electricity present was measured by the

gradual approach of the other knob of the micrometer. One experiment gave, for instance, the striking distance 1.475 lines.

The movable knob of the spark micrometer was then shoved back, the plate B charged in the same manner as before, and the disk A placed erect and brought within two lines of B; B now acted inductively on A, — E collected on A,* and reacting inductively upon B, brought about another arrangement of the electricity in the system opposite to it; the electricity collected more in A, and its density on the knob C is diminished; from this follows a reduced striking distance; for on bringing up the other knob of the spark micrometer until a spark passed, the striking distance was found to be 0.150. By the approach of the condenser, therefore, the electricity is accumulated upon A; its density on C on the contrary, is diminished, and in the proportion of 1.475 to 0.150, or in the last case it is only 0.102 of the former.

Fig. 44.



The electrical charge, which the jar gave to the plate was not perfectly equal in both cases, for beside the loss of charge which the jar suffered between the times of the first and second contact, it had imparted electricity to the plate at the first contact, hence at the second its charge must have been somewhat, although but a trifle, less than before. In order to correct this inequality in the quantities of electricity, *Riess* made a series of experiments, alternately with and without the condenser, and compared the striking distance of each experiment with the mean of the preceding and following ones. The results are arranged in the following table. Distance of the plates, two lines:

*Throughout his whole memoir *Riess* avoided the expression "*bound electricity*," (*gebundene electricität*,) for no other reason than because a false idea was connected with it. This term may be very properly united with a correct conception, and consequently I do not think an expression should be proscribed which has gone so much into common use. False conception of "bound," *i. e.*, disguised electricity, are not so generally disseminated as Riess seems to think; I never had any other view, than that which he presents, and he can hardly find much to object to in the presentation of the matter in my Treatise on Physics, unless he should take offence at a single word; the remark on the lower half of page 414 of the first volume of the first edition, (3d edition, 2d vol., p. 97,) are designed to remove every doubt as to the true meaning, and yet at the time I wrote that part, the memoir of *Riess* and the whole controversy on the nature of disguised electricity, was unknown to me, else I would have certainly suggested the proper experiments described in Section 17 of this report, and I also would have avoided here and there a few less accurate expressions, which, as I was not aware of any controversy, were used quite undesignedly.

[See note at the commencement of this Section.]

Striking distance in Paris lines.

Without condenser.	With condenser.	Mean.	Ratio.
1.475	0.150	1.406	0.106
		0.142	0.106
1.337	0.135	1.303	0.104
		0.132	0.104
1.270	0.130	1.244	0.105
		0.128	0.105
1.219	0.126		
			0.105

If we indicate by 1 the density of the electricity which is distributed upon the ball C when the plate B is charged while A is removed, more electricity will be attracted from C to B when the condenser in connexion with the ground is brought within two lines of the plate B, and thus the density of the electricity on C is diminished to 0.105.

The influence which the condenser A exerts upon the induction of electricity on the opposite insulated system B C, naturally depends upon the distance between A and B; the further A is from B, so much the less will the density on C be diminished on its elevation.

From a numerous series of experiments, conducted as those above described, *Riess* found for different distances of the condenser the following striking distances at the ball C, the striking distance without the condenser being taken as unity.

Distance of plates	2 lines.	5 lines.	10 lines.	20 lines.	30 lines.	50 lines.	∞
Striking distance	0.105	0.272	0.451	0.687	0.794	0.914	1

If we suppose that a perfectly free communication of electricity can be made at the knob C of the normal connecting wire, an accumulation of electricity will occur on the plate so long as the striking distance at the knob does not exceed a given quantity. Make this limit of density equal to 1. Suppose the insulated system, B standing alone, is charged to this limit. Now, if the condenser be brought near, and more electricity thus attracted to the plate B, and its density on C diminished, (say to $\frac{1}{n}$,) it is clear that n times as much electricity can be conveyed to the whole insulated system as before, until the density 1 is reached on C; hence the apparatus, in the presence of the condenser, can receive n times as much electricity as before.

In the above experiments, the density of the electricity on C is diminished by the approach of the condenser within two lines, to 0.105 or $\frac{1}{9.5}$; hence an accumulation of electricity 9.5 times as great as without the condenser.

For the different distances of the condenser in the above experiments the possible increase of density on the collector is in the following proportion:

Distance of plates	2 lines.	5.	10.	20.	30.	50.	∞
Possible increase of electric density on collector	9.50	3.67	2.21	1.45	1.25	1.09	1

This is the correct representation of the mode of action of the condensing apparatus. Correct views on the subject had long been held, but not so decidedly and clearly expressed.

In these experiments, C was connected with B by a wire 8 inches 5 lines in length. When a wire 18 inches 3 lines long was used instead, almost exactly the same relative numbers of the striking distance were obtained for the collector standing alone and in the presence of the condenser.

Consequently, when the conducting system of the collector is brought into contact with a constant source of electricity, there will be accumulated on the collector B, 2.21, 1.45, 1.25, &c., times more electricity when the condenser A connected with the ground, is 10, 20, 30, &c., lines distant from B, than if it were removed.

Riess made direct experiments to determine the increase of the quantity of electricity on the collector by the approach of the condenser under the above circumstances; that is, when the collector, during the proximity of the condenser, remained in communication with a constant source of electricity; the form of experiment was as follows.

First the ball C was touched with the knob of a Leyden jar, while the condenser was away; the jar was then removed, and the striking distance at C measured.

Next, the condenser communicating with the ground was placed at a given distance, C was brought into contact with the knob of the Leyden jar, the condenser jar removed, and the striking distance at C again measured.

The striking distance was found to be in the last case as many times greater than in the first as the electricity imparted to the plate B in the last instance was more than in the first.

A series of experiments gave as a mean the following quantities of electricity for the different distances of the plates:

Distance of plates	10 lines.	20.	30.	50.	∞
Electricity obtained	2.33	1.52	1.31	1.11	1

The difference between these observed numbers and the densities computed from the first experiments is really very small.

For distances less than 10 lines reliable experiments could not be made.

The proportion of the quantity of electricity on the collector, according as it stands alone during contact, or near the condenser, is called the *coefficient of accumulation* of the condenser. According to the above experiments, therefore, the coefficient of accumulation of the condenser is 2.21, 1.45, &c., when the plates are 10 lines, 20, &c., apart.

We shall see presently that this coefficient does not depend on the distance of the plates alone.

The determination of the density of the electricity on C by means of the spark micrometer renders the result very apparent, but is not suitable for accurate determinations, because the knob of the micrometer connected with the ground influences the induction of electricity on the opposite one. Instead of the spark micrometer, however, any other method of measuring the electrical density on C may be used.

Riess applied the torsion balance in a more accurate series. He found in this manner that when an electrical charge was imparted to the insulated system D B, (the knob of the micrometer connected with the ground being removed,) the condenser being away, and unity representing the electrical density of C, on the approach of the condenser at different distances, the density on C was as follows:

Distance of plates	2 lines.	3.	4.	5.	10.	15.	20.	50.	∞
Density on C	0. 173	0. 235	0. 286	0. 335	0. 492	0. 595	0. 683	0. 897	1

These results correspond very well with those found by means of the spark micrometer.

When the connecting wire between B and C was shortened, the following somewhat different numbers were found:

Distance of plates	2 lines.	3.	4.	5.	10.	15.	20.	50.	∞
Density	0. 155	0. 219	0. 274	0. 306	0. 488	0. 630	0. 688	0. 888	1

On the back of the collector the electrical density was diminished by the proximity of the condensor. *Riess* found that, on this surface, near its edge, the density was diminished in the following proportion:

Distance of plates	2.	3.	4.	5.	10.	15.	20.	50.	∞
Density	0. 260	0. 341	0. 412	0. 460	0. 617	0. 713	0. 628	0. 941	1

Thus it appears that on the back of the collector, near the edge, the density of the electricity is diminished by the proximity of the condenser far less than at the end C of the connecting wire, placed in the middle of the plate; hence *the coefficient of accumulation of the condenser is less when the body to be examined is placed at the edge than when at the middle of the collector.**

* This conclusion does not seem to me perfectly correct. The experiments show that when the constant source of electricity is kept at C the coefficient of accumulation decreases more than when the back surface of the collector is touched near the edge by the constant source of electricity. That it is the same whether the knob C or the middle of the collector itself be touched by the constant source is not yet proven, as it must be before the above conclusion can be admitted.

Larger condensing plates admit of a greater condensation of electricity than smaller ones, as *Munk af Rosenschöld*, has shown.

Experiments were made with plates 52 lines in diameter, under circumstances as near as possible the same as in the above series, that is the connexion of the collector was the same in both cases. Only the diminution of the electrical density was observed which took place at the end of the normal connecting wire (at the knob C?) on the approach of the condenser. In the following table the results obtained with the small plates are compared with those of the larger ones.

Distance of plates	2 lines.	3.	4.	5.	10.	15.	∞
Density with small condenser	0.232	0.330	0.393	0.443	0.688	0.768	1
Density with large condenser	0.155	0.219	0.274	0.306	0.488	0.630	1

Thus it is seen that the density of the electricity on the normal conductor of the small plates is not so much diminished by the proximity of the condenser as by the use of the larger plates, and consequently that in condensing with large plates, a greater accumulation of electricity is possible on the back surface of the collector itself than in the use of small plates.

The density of the electricity on the collector plate also depends upon the manner in which conducting connexion is made with the condenser.

In the last experiments made with the small plates, the conducting connexion with the condenser was normal to its plane; but the connecting wire was next placed at the side of the projection from the plate, so that it was about five lines distant from the plate and parallel with it. (The arrangement as thus described is not quite clear to me. M.)

The density of the electricity on the normal projection, or handles of the collector, was now observed for different distances of the condenser, and the results compared with those obtained by the normal conductor of the condenser plate.

Distance of plates	2 lines.	3.	4.	5.	10.	∞
Density, (parallel conductor)	0.190	0.269	0.340	0.408	0.597	1
Density, (normal conductor)	0.232	0.330	0.393	0.443	0.688	1

With the conducting wire running parallel to the condenser, a less density is found for each distance of the plates, on the normal conductor of the collector plate, than when the conductor of the condenser plate is normal; consequently the conductor of the condenser plate being parallel, the condensor is susceptible of a greater accumulation of electricity than when the conductor is normal.

Riess next sought to determine the quantity of electricity disguised on the condenser plate. It is sufficient here, to present only the results of his experiments with the larger condenser. Representing by 1 the quantity of electricity on the collector, the following quan-

tities of electricity are found on the condenser at different distances of the plates.

Distance of plates	2 lines.	3.	4.	5	10.	15.	20.	50.
Quantity of induced electricity on condenser	0. 911	0. 887	0. 854	0. 823	0. 689	0. 612	0. 500	0. 263

§ 27. Electrical effects of flame.—The electrical properties of flame have been described in a memoir by *Riess*, which may be found in *Poggendorf's Annalen*, vol. LVI, p. 545. In the introduction he gives historical notices of the experiments and views previously presented on this subject. We will only remark here, that *Gilbert* and *Kircher* were acquainted with the electrical effect of flame; *Priestly* proved experimentally that it was a conductor of electricity, and *Volta* compared the electrical action of flame to that of metallic points.

The electrical action of flame may be thus concisely characterized: If an electrified conductor be furnished with a flame, it will at once lose its electricity, which issues though the flame, as through a point fixed on the conductor; if, on the other hand, a flame be brought into the neighborhood of an electrified body, the flame draws off the electricity, just as a metallic point does in a far less degree. On placing a flame on the knob of a Leyden jar which is near an electrical machine in operation, the jar charges itself as though the knob had been connected with the conductor of the machine. *Volta* applied burning sponge to his electroscope, in order to attract atmospheric electricity by this means.

Although *Volta* was well aware that flame was a conductor and that it acted like metallic points, and thus had the elements of a correct explanation, yet his views on the action of points themselves were somewhat erroneous, since he believed that the emission as well as the absorption of electricity by points was a consequence of the electrical wind. In flame the ascending current of air, according to his view, replaced the effect of the electrical wind.

The electrical wind appears, it is true, when points are strongly charged and favors the emission and absorption of electricity, but the action of points is not dependent upon this wind; the action takes place even in electrical charges which are too weak to cause the electrical wind to appear.

According to *Volta's* explanation, an actual communication of electricity takes place in the electrical action of flame. That the charging and discharging action of points does not always depend on the immediate transfer of electricity is known; *Riess* sought to prove this also for flame, experimentally; he explains the action of flame in the following manner.

A dense current of steam constantly issues from flame, rising as a continuous stratum into the air. But it preserves this form only for a small elevation.* As the air presses on the steam from all sides,

* [This passage, which is correctly transcribed from *Riess'* memoir, is here literally translated. That the steam should be decomposed after having been formed by combustion, is contrary to what we know of flame, and the author has given no reason for such a view.]

and the latter, decomposed by the white heat, unites with particles of air, the continuous mass is broken and separated, and only threads of it remain, which are diffused more and more, and finally scattered in the air.* Hence from flame conducting electricity threads issue, which being separated from each other by the non-conducting gases and hot air, necessarily flow away in ends and points. This being granted, flame must be considered as a good conductor of electricity, furnished with a number of points extending in every direction into the air, and such, too, as to exceed in perfection all the points existing in nature.

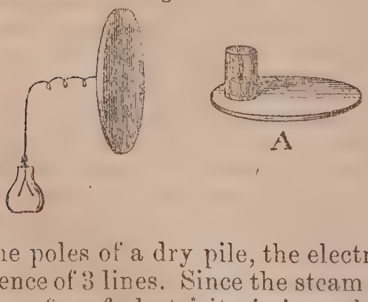
The quantity of electricity issuing from a conductor furnished with points, is as much greater as the points are more perfect; the least traces of electricity are also removed by flame. The electrical density is much greater on a point than on any other part of a conductor, at the steam points of flame the density is therefore very great; the electricity accumulated at the steam points acts then inductively upon neighboring insulated conductors. If the accumulation of the electricity attracted to the parts of the insulated conductor, which lie nearest the electrical steam points, is great enough, it will escape, and the conductor will remain charged only with the electricity which is repelled by the electricity of the flame being of the same kind; the insulated conductor therefore remains charged with the same electricity which the flame has, without that of the flame having gone over to it.

On the other hand, if the flame be brought near to an electrified body, the steam points will become electrical by induction, but their electricity escapes, and the insulated conductor, on which the lamp is placed, remains charged with the same electricity which the neighboring inducing electrified body possesses, without this electricity having passed from the electrified body to the conductor provided with the lamp.

This view of the subject is justified by the following experiment:

A small metallic spirit-lamp, surrounded by a metallic cylinder 13 lines high, was placed on a properly insulated copper disk A, 3 inches 11 lines in diameter. About 3¾ inches from the lamp was placed a second copper disk B, (fig. 45,) connected with the electroscope *b*, and kept in a vertical plane by an insulating shellac handle. The point of the wick and the middle of the disk B were at the same height.

Fig. 45.



When the lamp was lighted and A electrified by contact with one of the poles of a dry pile, the electroscope immediately indicated a divergence of 3 lines. Since the steam of the flame ascends vertically, a direct transfer of electricity is improbable. If it does take place, A and B must necessarily be in conducting connexion through steam, and the electroscope should collapse as soon as A is touched. But by touching

[* This explanation is unsatisfactory, since super heated steam does not conduct better than heated air; all we know at present relative to this matter is, that a flame acts as an assemblage of perfect points]

A, the leaves of the electroscope *b* fell only to $2\frac{1}{2}$ lines. Hence there was no conducting connexion between B and the lamp, and the charging of B took place in the way indicated above.

If B was electrified, and while the lamp burned, A was touched, the electroscope collapsed slowly, stood at 3 lines divergence, and even after two minutes the divergence was $2\frac{1}{3}$ lines. B being held horizontally over A, the steam of the lamp struck B; consequently a conducting connexion existed between A and B. In this case, when the experiments just described were repeated, the electroscope *b* at once collapsed when A was touched.

From the results of these experiments, it appeared that the effective steam points extended far beyond the flame and the metallic cylinder surrounding the lamp, otherwise the cylinder would have destroyed the action of the points, as, in fact, is the case with incandescent bodies.

When burning spunk was laid upon A, and B properly insulated, was held horizontally over A, A being electrified by contact with one of the poles of a dry pile, the electroscope *b* immediately diverged; but this did not happen when the burning spunk was surrounded by a metallic cylinder 13 lines high by 9 in diameter. This shows that the ascending smoke in this case was not a conductor. The action of incandescent bodies, therefore, is not, like that of flame, produced by steam. At the place where the mass burned, a hole was formed whose edges were prevented from burning by the carbonic acid, &c., produced. Where a number of such holes came together, a projection of unburnt mass remained. By continued burning, these projections became pointed; and to these points, standing out everywhere over the burning body, all the consequences are applicable which were developed above for the steam points.

Slow match, pastiles, &c., behaved like glowing spunk.

Riess modified these experiments in various ways, and always obtained results confirmatory of his theoretical views. In all these experiments the combustion of the ignited bodies was made as perfect as possible. Spunk and charcoal pastiles (made like ordinary fumigating pastiles) were kept burning by constant blowing, and cleared of ashes; and the spirit-lamp used only for intense ignition. By such precaution, every disturbance of the described effects was avoided. When, on the contrary, the ignition of the body under examination is not perfect, an experiment with one of the kinds of electricity is found to succeed often much more easily, and in a more striking manner, than with the other, which is not the case in perfect ignition.

The disk A was placed in a vertical position, and B parallel to it, and then on A was fastened a pastile, (a small cone made of pulverized charcoal and some saltpetre, mixed with gum tragacanth,) which was directed towards B. When the pastile was ignited over half of its surface, and covered with ashes, A was touched with one of the poles of a dry pile. If it was the positive pole, the electroscope *b* diverged very slowly, and at most only 2 lines; but if the negative pole of the dry pile was applied to A, the electroscope diverged quickly, and more than 5 lines. On the other hand, an electroscope connected with the pastile and the plate A diverged more rapidly, and to a

greater extent, when the opposite disc B was electrified positively than when negatively. It therefore seemed as though negative electricity escaped from the pastile more easily; while the positive, on the contrary, was absorbed by it more readily.

Riess explains these peculiar phenomena by the well known fact that, in burning charcoal, a development of electricity takes place, and, as observed by *Volta*, this development is strongest with moderate ignition, with a weak blast and a retarded combustion of the coal.

In this case the ascending carbonic acid is positively, and the coal negatively electrical; the points being then negatively electrified already of themselves, must act more powerfully when — E is imparted to them in addition, than when + E is imparted; hence the above described difference of the phenomena in positive and negative charges explains itself perfectly.

The coal acts by its negatively electrified points, and not through the positively electrified steam, else we should obtain the stronger effects with the same electrical charge, which, in the above experiment, gave the weaker effect. This case is also observed in Davy's lamp without flame.

On the disk A (fig. 45) a brass flameless lamp with a feebly glowing spiral was placed; the lamp, 10 lines high, was surrounded by a cylinder of sheet copper 13 lines high; A being positively charged, the electroscope *b* diverged more than by a negative charge of A. When A was provided with an electroscope and B charged by contact with one of the poles of a dry pile, the electroscope diverged more by a negative charge of B.

On the above mentioned memoir of *Riess*, a discussion has arisen as to the electrical effects of flame between *Riess* and *Van Rees*.—(Pogg. Ann., LXXIII, pp. 41 and 307.) *Van Rees* first denies the existence of steam points. He sustains himself by the fact that these points are not visible when the shadow of a flame is examined, the shadow being obtained by letting the light pass through the illuminating apparatus of a solar microscope into a dark room, and bringing the flame into the diverging cone of light.

On the contrary, *Riess* says that he who imagines that these points can cast shadows, may abandon this view without trying the experiment. But it is a fact that, above the flame acting electrically, a column of steam does exist, which is a good conductor, and which soon loses itself in the badly conducting air; the cold air divides the conducting mass and diffuses it.

Indeed, this view has the greatest probability on its side, and since *Van Rees* himself says, "a flame is, on the whole, (including the mass of steam directly above it,) to be regarded as a conductor," there is properly no great difference between the views of the two physicists, and the controversy on this point is almost nothing but a strife about words.

In explaining the action of flame, *Van Rees* also starts from the action of points; he says, if a point be placed on the conductor of an electrical machine, an unbroken current of electrified air arises, acting inductively upon the nearest conductor.

Two metres from the conductor of the electrical machine, furnished

with a point, an electroscope was placed; as soon as the machine was turned the leaves diverged, and this divergence remained when the conductor was discharged; in spite of this continued divergence, the electroscope had no permanent charge, but the leaves diverged in consequence of the inductive action of the air electrified by the point, which air cannot lose electricity by the discharge of the conductor. *Van Rees* showed that the electroscope actually had no permanent charge by the collapse of the pendulum when he took the electroscope to an adjoining room, and by its diverging again when he placed the instrument in its former position. By continued turning of the machine, the particles of air electrified at the point were scattered, they, in part, reached the electroscope, and thus communicated to it a permanent charge.

No objection can be urged against this.

Van Rees now applies these views of the action of points to the action of flame; air, ascending from flame, is charged by it and can then act inductively on neighboring conductors. When the electroscope *b*, in the first experiment of *Riess*, mentioned on page 410, appeared to be permanently electrified, according to *Van Rees*, this was only a consequence of the inductive action of the electrified air above the flame, which air, on discharging the plate A, cannot be itself discharged because it is an insulator. The inductive action which proceeds from flame, *Van Rees* considers much too feeble to effect so great an accumulation of attracted electricity in the plate of an electroscope brought near to it (the plate B in *Riess'* experiment) as to cause a current in consequence of which the electroscope should remain charged. On this point it is evident that no general rule can be given, since so much depends upon special relations, such as the dimensions of the plates, the dimensions of the inducing body, the relative distances, &c.

The difference between the views of the two physicists is essentially as follows: According to *Riess*, the ascending conducting mass of steam, going off in single threads, acts inductively upon the neighboring conductors; on the other hand, according to *Van Rees*, the inductive action proceeds from the non-conducting mass of air above the flame, to which the electricity is communicated by the conducting flame.

The truth may lie between these two views. It is beyond doubt that a conducting column of steam forms over flame, and it is highly probable that it is diffused in fine conducting threads. If this mass of steam, with its points, is electrical, it must act inductively on the neighboring conductors, according to the view of *Riess*. But how far the column of steam continues to be a conductor is uncertain. Most of the gases and vapors formed by ignition lose their conducting power by cooling; but they will retain the electricity imparted by flame, and thus an electrified non-conducting mass of gas forms above the electrified flame and its conducting parts, which gas also acts inductively on neighboring conductors, in accordance with the view of *Van Rees*.

It is very evident that, in powerful excitation of electricity, the transfer of electrified air and particles of dust is added to the above-

described inductive action, and may easily effect the greater part of the charging and discharging.

Petrina has endeavored to explain the electrical effect of flame in a very peculiar manner, (Pog. Ann. LVI, 459.) He thinks that the oxygen rushing toward the flame enters into chemical combination only under a definite electrical condition, and he supposes that this condition continues to a considerable distance from the place of combination.

Petrina has not yet established this hypothesis.

SECTION THIRD.

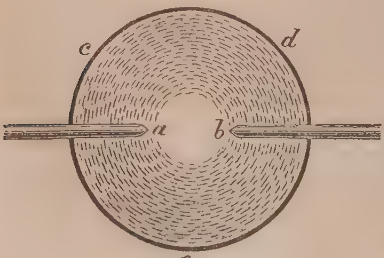
THE LEYDEN JAR AND EFFECTS OF THE DISCHARGE.

§28. Abria on some of the mechanical phenomena accompanying electrical discharge.—When the discharge of a Leyden jar is passed between points, and a glass plate, strewed over with a fine powder, is placed beneath the path of the spark, after a few discharges the powder is observed to be arranged in curves with some regularity.

Abria first observed and described this phenomena, (Ann. de Chim. et de Phys., LXXIV, 186; Pog. Ann. LIII, 589.) A clear conception cannot be obtained from his memoir of what kind of curves these are, and this is chiefly due to the fact that the figure, which should serve for the purpose of explaining the matter, does not correspond at all to the text. Even after having myself become acquainted with the phenomenon by experiment, the figure attached to the memoir is still incomprehensible.

In order to investigate the subject I made the experiment in the following manner: The interior coating of a jar was connected with the conductor of the machine. In the path which the electricity had to traverse from the interior coating to the exterior, *Henley's* universal discharger was placed. A glass plate was laid on its stand, thinly sprinkled with minium or with flour of sulphur. The result was the same for both powders; the particles arranged themselves as shown in figure 46.

Fig. 46.



The two points between which the sparks passed are represented by *a* and *b*; beneath them is the plate *c d e*, on which the regularly strewed powder arranged itself after repeated discharges, in the manner represented by the curved lines.

The curves are modified, of course, when the distance of the plate from the line of the points *a* and *b* is changed. They are not continuous, but composed of short broken portions, as shown in the figure, and I cannot, therefore, comprehend how

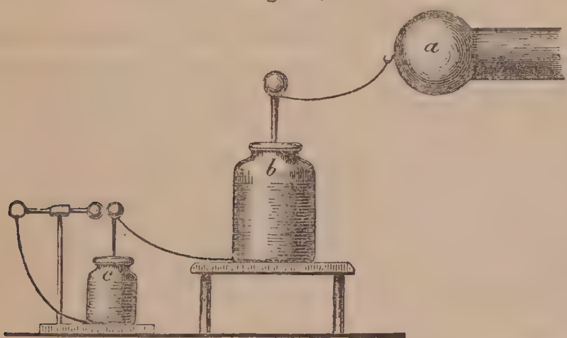
Abria could so far investigate their nature as to decide that they are not ellipses, as it would appear at first sight, but that they are more complicated figures.

Abria ascribes this effect to the mechanical shock which the discharge of the spark occasions in the air, and supports this view by producing similar phenomena from slight explosions.

If small soap bubbles, filled with detonating gas, are exploded upon a marble slab strewed with powder, or if we produce the shock by exploding pellets of fulminating powder on the powdered plate, similar curves will be obtained, which, however, in the latter case, will not be so regular as when produced by the explosion of the small bubbles of the detonating mixture.

§29. MEASURE OF THE CHARGE OF THE BATTERY.—*Riess* used the following process for measuring the quantity of electricity accumulated in a jar or battery. (Pog. Ann. XL, 321.)

Fig. 47,



The jar or battery *b* (figure 47) to be charged was placed upon a table insulated by glass legs, and its inner coating connected with the conductor *a* of the electrical machine, the outer with the inner coating of *Lane's* measuring jar. The outer coating of the measuring jar was connected with a large metallic surface (a zinc roof) by a wire, so that perfect conduction could be secured.

The battery having received + E from the conductor of the machine, the repelled + E of the outer coating of the battery goes to the interior of the measuring jar, and charges it; but this charge having attained a certain limit a discharge of the measuring jar ensues, and a new portion of — E can pass from the interior coating of the latter to the exterior of the battery, because the original state of the inner coating of the measuring jar is restored by the discharge, except an inconsiderable residue, which, however, remains the same after all the subsequent discharges. As often as a discharge of the *Lane* jar follows the continued turning of the machine, the same quantity of — E passes to the outer coating of the battery, and the charge of the battery is increased by the same quantity of electricity; the charge of the battery, therefore, *is proportional to the number of discharges of the measuring jar.*

The distance of the knobs of the measuring jar, in *Riess's* experiment, was first ½ a line, afterwards 1 line; it remained constant, however, during each series of experiments.

Riess indicated the quantity of E collected on the outer coating of the battery by q. The unit by which q was measured was the quantity of electricity imparted to the battery for each discharge of the

measuring jar. Suppose $q = 8$; this means the charge of the battery has been continued until 8 discharges of the measuring jar have occurred.

The density of the electric charge of the battery depends, not only upon the quantity of E imparted to it, but also upon the size of the surface over which it spreads. If the same quantity of electricity is diffused over a double, treble, &c., surface, its density becomes twice, thrice, &c., as small; in short, the density of the E is inversely proportional to the magnitude of the surface of the battery, but is directly proportional to the quantity of E imparted; the density upon the charged battery may then be expressed by

$$\frac{q}{s},$$

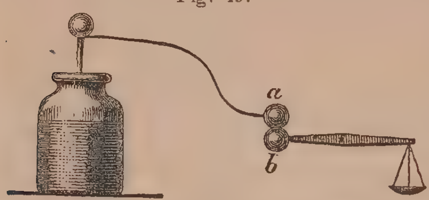
q indicating the quantity of imparted E, s the size of the surface.

In his experiment, *Riess* used jars as nearly alike as possible, so that the surface of the battery was proportional to the number of jars. The surface of one jar was taken as the unit of area.

To attain accurate results, the charge of the battery must be made continuously by contact, and not by sparks passing from the conductor.

§ 30. Repulsion of the inner coating of the battery.—If the inner coating of the first jar of a battery be connected with a wire terminating in a metallic knob, as shown in fig. 49, the free electricity of this coating of the charged battery will be diffused over the knob. In contact with the first is a second knob b fastened to the end of a glass rod, which may readily turn about its middle point, and bearing at its other end a small scale pan. The scale is loaded until it is in equilibrium with the knob b.

Fig. 49.



The glass rod b was 12 inches long, and had at the middle a piece with steel pivots resting upon the rounded edges of two agate plates.

1, 2, 3, 4 grains being now placed in succession upon the scales, it was found what quantity of E should pass through the measuring jar from the outer coating of the battery before the knob b was repelled.

When the battery consisted of only one jar, and 1 grain was placed in the scale, repulsion followed after 2 discharges of the measuring jar, 3 grains being placed in it, 4 discharges were required.

Each experiment was repeated and the mean of the two taken. The same experiments were then made with a battery of 2, 3, . . . to 5 jars. The results are comprised in the following table:

s	1	2	3	4	5
p	q	q	q	q	q
1	2.0	4.5	7.0	8.7	10.0
2	3.5	6.0	10.0	12.0	15.5
3	4.0	7.7	11.7	15.0	20.0
4	4.5	9.0	13.3	17.7	24.0

The quantity 4.5, according to the table, sustains a weight of 4 grains when only 1 jar is used, while the same quantity 4.5, divided between two jars, sustains only 1 grain; thus the effect, the quantity being the same, is inversely proportional to the square of the surface, since with a double surface the effect is one fourth.

Let us consider the experimental series with 2 jars. The quantity 4.5 sustains 1 grain double this quantity, 9.00 sustains a weight four times as great or 4 grains; hence, the surface being the same, the weight sustained, or the force of repulsion, is proportional to the square of the quantity.

We conclude from the above data that the repulsion of the balls is directly as the square of the quantity of electricity, and inversely as the square of the surface, so that,

$$p = a\frac{q^2}{s^2} = a\left(\frac{q}{s}\right)^2,$$

or the repulsion of the balls is proportional to the square of the density of the E, $\frac{q}{s}$ indicating this density.

Having deduced this law from observations selected at random, we have now to show how closely the rest of the observations agree with it.

According to the law, a double quantity of electricity produces, with the same number of jars, a quadruple effect; each value of q, therefore, on the lowest horizontal line, must be double the value of q at the top of the same vertical column. This, however, is rigidly true only for the series under the head of 2; the quotients

$$\frac{4.5}{2}=2.25;\quad \frac{13.3}{7}=1.90;\quad \frac{17.7}{8.7}=2.03;\quad \frac{24}{10}=2.40$$

vary more or less from 2. Taking the mean of all the five quotients, (that of $\frac{9.0}{4.5}=2$ included,) we get the number 2.11, which in fact is very nearly equal 2.

The quotients, obtained by dividing the values of the second line by the value of q in the upper horizontal row, should, according to the law, be equal to $\sqrt{2}=1.41$. The mean of the five quotients is 1.48.

If the numbers of the first and third lines be compared in the same manner, the mean of the five quotients will be the value 1.82, while, according to the law, it should be equal to $\sqrt{3}=1.73$.

The repulsion being proportional to the square of the density, according to the above law, with like effects, or equal values of p, the quantity of electricity must increase in proportion to the number of jars; hence the numbers of the column headed with 2 must be twice as great as those on the same line under 1; or in other words the quotients $\frac{4.5}{2}$, $\frac{6.0}{3.5}$, $\frac{7.7}{4.6}$, $\frac{9.0}{4.5}$, should all equal 2. Computing these

quotients and taking their mean, we find the value 1.97 deviating but little from 2.

In like manner comparing the third, fourth, and fifth vertical series of the values of q with the first, we get as mean values the quotient:

	3.05	3.84	4.94
instead of	3.	4.	5.

Thus it is seen that the mean values agree quite well with the law.

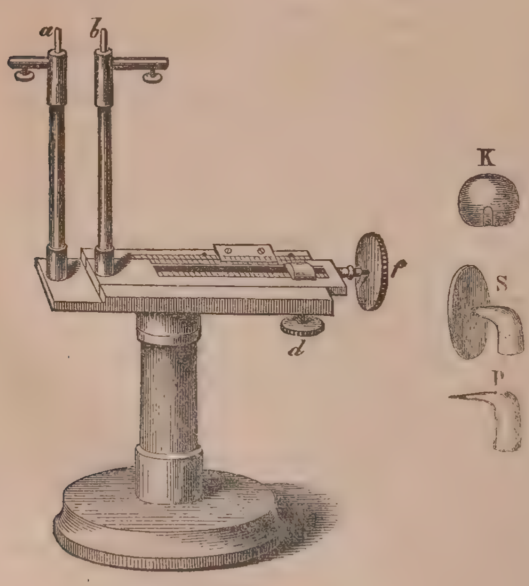
It has already been proved by *Coulomb's* experiments that two insulated conductors which are in contact, after receiving electrical charges, repel each other with a force proportional to the square of the electrical density.

In the experiments just described we do not directly measure the density of E upon the balls, but the quantity induced upon the outer surface of the battery. The accordance of our results with *Coulomb's* law therefore proves that the density of the free E of the inner coating, producing the repulsion of the knobs, is always in the same proportion to the induced E on the outer coating; or, in other words, that the co-efficient of condensation is independent of the quantity of E in the interior of the battery.

§ 31. STRIKING DISTANCE OF THE BATTERY—The experiments of *Riess* on this subject (Pogg. Ann. XL, 332) confirm the fact, which had been already discovered by *Lane* and *Harris*, that the striking distance of the battery is proportional to the density of the electricity.

In order to measure accurately the striking distance of the battery, *Riess* used an apparatus, which he termed the *spark micrometer*, represented in figure 50.

Fig. 50.



Each of the brass pins, a and b, is attached to a piece of brass having a horizontal arm for clamping wire and insulated by a glass support. One of the rods is fixed, the other is on a slide which moves by means of the screw f along a graduated scale. When the clamp screw d is loose, the slide may be moved freely by the hand; but when d is screwed up, the fine adjustment is made by means of f, because by screwing up d the nut belonging to f is clamped against the lower metal plate. The whole apparatus rests upon a glass support $2\frac{1}{2}$ inches high.

Different metallic bodies can be placed upon the pins a and b; knobs K, $6\frac{1}{2}$, discs S, $8\frac{1}{2}$ lines in diameter, points P, &c.

In the first of the experiments now under consideration knobs were used.

The experiments were made in the following manner: One of the arms was brought into good conducting contact with the inner, the other with the outer coating. The jar or battery was charged as before with the *Lane* jar. Observation was made of the number of sparks which passed in the measuring jar before a discharge of the battery took place at a given distance d between the knobs of the spark micrometer. The unit for d was $1\frac{1}{2}$ lines.

The results of the experiments are comprised in the following table, s and q having the usual signification:

s	2	3	4	5
d	q	q	q	q
1		3.0	3.5	4.3
2	3.0	5.5	7.0	8.5
3	4.6	8.0	10.1	12.5
4	6.4	10.3	13.5	16.0
5	7.5		16.0	

Comparing any value of q with those under it in the same column, the quotient is nearly the same as that of the corresponding values of d. Take for example the column headed 4, the case in which a battery of 4 jars was used, we see that the quantity 3.5 gives the striking distance 1; a double and quadruple striking distance gives double and quadruple quantity, namely: $7 = 2 \times 3.5$, and $13.5 = 4 \times 3.5$ nearly. Thus the striking distance in the same battery is constantly proportional to the quantity q of imparted electricity.

The other experiments confirm this. The numbers of the second column of values of q, divided by those of the first, give as a mean the quotient 1.92, nearly 2, which is the quotient of the corresponding striking distance 2 and 1.

The second and third, second and fourth, second and fifth horizontal series of values of q in like manner give the mean quotients,

$$1.47 \qquad 1.95 \qquad 2.39,$$

or nearly

$$1.5 = \tfrac{3}{2}, \; 2 = \tfrac{4}{2}, \; 2.5 = \tfrac{5}{2},$$

which are the ratios of the corresponding striking distances.

The quantity 10.3 divided among 3 jars gives the striking distance 4; the same quantity (very nearly, viz: 10.1) divided among 4 jars gives the striking distance 3. Thus, with equal quantities of electricity, the surface increasing from 3 to 4, the striking distance diminishes in the inverse ratio of 4 to 3; the striking distance therefore is directly as the quantity and inversely as the surface, hence

$$d = b\frac{q}{s}$$

or, in other words, *the striking distance is proportional to the density of the accumulated electricity.*

If this law be generally true, and the striking distance inversely proportional to the surface of the battery, but directly proportional to the quantity, for equal striking distances, the quantity must increase in the same ratio as the surface.

In the above table the numbers of the same horizontal series should be always proportional to the values of *s* placed over them. Thus $\frac{5.5}{3}$, $\frac{8.0}{4.6}$, $\frac{10.3}{6.4}$ should be equal $\frac{3}{2}$, also $\frac{3.5}{3}$, $\frac{7.0}{5.5}$, $\frac{10.1}{8.0}$, $\frac{13.5}{10.3}$ equal $\frac{4}{3}$ &c., which is nearly true for the averages.

Riess found the law, that the striking distance is proportional to the density of the accumulated E, to hold good for the case in which the spark passed between two parallel metallic discs, or between a ball and a disc.

He found, that under otherwise like circumstances, the striking distance between two discs is greater than between two balls, and that with parallel discs the spark passed not in the middle, but at or near the edge. For a ball and disc the striking distance is greater than for two balls and less than for two discs.

§ 32. Striking distance of the battery independent of the conducting circuit.—It was formerly believed that the striking distance of the battery was dependent upon the nature of the conducting circuit, that it was greater with good metallic connexion, less with poorer conductors. *Riess* has shown that this is not the case. (*Pog. Ann.*, *LIII*, 1.)

The experiments were arranged in the following manner: One of the pins of the spark micrometer was connected with the inner coating of the battery by a thick copper wire; another thick wire of copper led from the other pin to one of the arms of *Henley's* discharger, the other arm of which was placed in good conducting contact with the outer coating of the battery. Between the arms of the discharger the following were interposed in succession:

1. A copper wire 4 lines in length $\frac{1}{2}$ a line in diameter.
2. A platinum wire 102 inches long 0.052 lines in diameter.
3. A glass tube 8.3 inches long 4.5 lines diameter, filled with water.

Thus in turn a very perfect, a metallic, an imperfect, though metallic and finally a very imperfect conductor was inserted. The results of the experiment are given in the following table:

		Conducting circuit.		
		Copper wire.	Platinum wire.	Tube of water.
s.	d.	q.	q.	q.
3	1	6	6	6
	2	10.2	10.5	10.5
	3	15	15	14.5
4	1	8	8	8
	2	14.5	14	14
	3	21.5	19.7	19.5
5	1	10	10	11
	2	18	19	19
	3	27	25.5	26

This table shows that with an equal number of jars *s*, and for equal distances *d* of the knobs of the spark micrometer, the value of *q* remains very nearly constant, whether the platinum wire, the copper wire or the tube of water be interposed. With equal charges, then, the striking distance is the same however the connector may be composed.

The striking distance of the electrical battery, consequently, is perfectly independent of the nature of the closing substance, provided the surfaces between which the discharge takes place remain unchanged.

Though the striking distance is not changed by the nature of the circuit, the latter has a great influence upon the sparks themselves. Five jars of a battery, with a certain charge, and using the copper wire, produced sparks of dazzling brilliancy, 1½ lines long with a rattling report; while by using the platinum wire, with an equal charge, a spark of equal length was obtained, but the light was feeble and the report faint; and with a tube of water the spark was scarcely perceptible.

§ 33. Quantity of electricity disappearing by discharge at the striking distance.—When the battery is discharged at the striking distance, a perceptible charge remains behind, which produces a second spark on bringing the knobs nearer together. This fact can be easily shown by the measuring jar. Place its knobs about two lines apart, and charge until a spark passes; now approach the knobs towards each other and a second spark will pass.

Riess has shown in the last mentioned memoir, that the quantity of electricity disappearing on discharging the battery at the striking distance, is always in the same ratio to the entire charge, and that it is the same whether the closing circuit is composed of better or worse conducting metallic wires.

The experiments were arranged precisely like those whose results are given in the last table; in one of the series a copper wire, and in the other a platinum wire was used with *Henley's* discharger. After the discharge had taken place at the striking distance, and a part of the battery's charge had thus disappeared, it was recharged

until another discharge occured. The number of sparks of the measuring jar required to produce the first discharge of the battery was counted, then the number of sparks necessary to replace the quantity of electricity which had disappeared at the first discharge.

The previous table shows how large the entire charge was under different circumstances, when the discharge took place at a given striking distance, and the following table shows how much electricity the battery had to receive again, to obtain the second discharge at the same striking distance:

		CONDUCTING CIRCUIT.	
		Copper wire 4‴.	Platinum wire, 102 in.
s.	*d.*	*q′.*	*q′.*
3	1	5.0	5.0
	2	8.8	8.7
	3	13 0	12.5
4	1	6.5	6.5
	2	12.5	11.7
	3	17.0	17.0
5	1	9.0	9.0
	2	15.0	16.5
	3	22.5	22.5

We see from this table that the quantity of electricity q', which has to be imparted to the battery after the first discharge at the striking distance, to produce a second discharge at the same distance, or the quantity disappearing by discharge at the striking distance, is always almost exactly the same, whether the short copper or long platinum wire be interposed.

With three jars, and at the distance 1 of the knobs of the spark micrometer, the quantity of electricity required for the first discharge was $q = 6$; to produce the second discharge, the battery had to receive afterwards the quantity $q' = 5$; thus $\frac{5}{6}$ of the entire charge disappeared at the distance 1, or, in other words, we have

$$\frac{q'}{q} = \tfrac{5}{6} = 0.833...$$

For $s = 4$, $d = 1$, we have $q = 8$, $q' = 6.5$, hence

$$\frac{q'}{q} = \frac{6.5}{8} = 0.812...$$

For $s = 5$, $d = 1$, we have $q = 10$, $q' = 9$, hence

$$\frac{q'}{q} = \frac{9}{10} = 0.9.$$

For $s = 5$, $d = 3$, we have $q = 27$, $q' = 22.5$, hence

$$\frac{q'}{q} = \frac{22.5}{27.} = 0.833.$$

For $s=4$, $d=2$, we have $q=14.5$, $q'=12.5$, hence

$$\frac{q'}{q}=\frac{12.5}{14.5}=0.862.$$

Thus it is evident that, under the most different circumstances, very nearly the same portion of the entire charge disappeared on discharging at the striking distance. As a mean of all the experiments presented in the last two tables, it appears that 0.846 or $\frac{11}{13}$ of the entire charge disappears after discharge at the striking distance, whether good or bad metallic conductors are used, and consequently $\frac{2}{13}$ of the entire charge remain as residue.

When *Riess* substituted parallel metallic plates for the knobs on the spark micrometer, an experimental series gave for $\frac{q'}{q}$ the mean value 0.849; and when an interruption of 0.3 line was made in the closing circuit, he had $\frac{q'}{q}=0.842$, or almost exactly the same value for the quantity of electricity disappearing at the striking distance.

The value $\frac{q'}{q}$ is probably dependent upon the thickness of the glass of the battery, but no experiments have as yet been made to determine this.

§ 34. Results by the ordinary mode of discharge.—From these experiments we may easily determine what takes place in the ordinary mode of discharge, in which a movable knob, connected with the outer coating, is brought into contact with the fixed knob of the inner coating. When the movable knob arrives at the striking distance, which we shall denote by d, $\frac{11}{13}$ of the charge disappears and $\frac{2}{13}$ remain; another discharge can take place only when the movable knob is approached to $\frac{2}{13}\,d$, at which distance again $\frac{11}{13}$ of the remaining charge disappear; a third discharge follows when the movable knob is brought to $(\frac{2}{13})^2\,d$, &c. Suppose the original striking distance to be $1\frac{1}{2}$ lines, the series of discharges take place at the following distances:

1.5; 0.23; 0.035; 0.0055 lines;

the third of which does not differ sensibly from contact. In the ordinary mode of discharge, therefore, the closing circuit receives several discharges, one after another.

§ 35. Results by discharge at the striking distance.—In discharge at the striking distance so great a quantity of electricity disappears that merely a small approximation of the knobs does not produce a second discharge; but the striking distance must be reduced to $\frac{2}{13}$ of the original. That so great a quantity of electricity as $\frac{11}{13}$ of the entire charge should disappear seems to indicate that the discharge, even at the striking distance, is successive; the air is rarefied by the transfer of the first quantity of electricity, and thus the transfer of a new portion is rendered possible, which could not have taken place if the resistance to be overcome had not been diminished by the rarefaction of the air. The passage of electricity continues until the charge of the battery has become so feeble that at the constant distance of the

knobs, in spite of the little resistance still due to the rarefied air, a spark can no longer pass. The air having regained its ordinary density between the knobs, a *considerable* approximation of the latter is necessary to make another discharge possible. By discharging at the striking distance, therefore, the electricity is successively transmitted.

A proof of this successive discharge exists in the fact that the remainder of the charge is considerably greater, and consequently a smaller quantity of electricity disappears if the first discharge occasions a break in the circuit, as is the case, for instance, when a fine wire, interposed in the circuit, is fused which we will consider more at length hereafter.

A further proof of successive discharge at the striking distance is the circumstance that the residual charge is considerably greater when a tube of water is introduced into the circuit.

Instead of the copper or platinum wire mentioned on page 420, the glass tube with water was interposed, and a series of experiments with this circuit gave the following results :

s.	d.	Entire charge, q.	Residual charge, q'.
3	1	6.	3.5
	2	10.5	7.
	3	14.5	10.5
4	1	8.	4.5
	2	14.	9.
	3	19.5	13.5
5	1	11.	5.
	2	19.	11.7
	3	26.	17.

Although the striking distance here is the same under like circumstances, as in the metallic circuit, the quantity of electricity that disappears is much less than when the metallic circuit is used. With the latter $\frac{q'}{q} = \frac{11}{13} = 0.846$, with the water it is only $\frac{5}{8} = 0.625$; the remainder of the charge then amounted to $\frac{2}{11} = 0.154$; in this case it is $\frac{3}{8} = 0.375$; thus the residue is here more than double as great as in the former case.

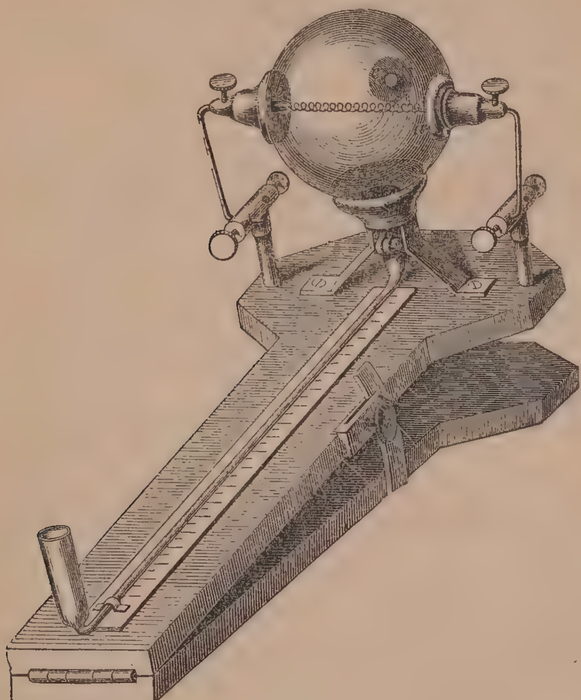
Riess explains this in the following manner: A battery being charged, the quantities of electricity on the outer and inner coatings are in a given ratio to each other. An excess on the inner coating, which is an aliquot part of the whole quantity, exists in the interior. The quantity of induced electricity on the exterior coating is also in a certain ratio to this excess. At the first moment of the discharge equal portions of the electricity of the inner and outer coatings disappear, the former ratio is destroyed, and there is now proportionally more free electricity on the inner coating than in the state of perfect charge, and in this way a further discharge is favored. But when the tube of water is introduced the discharge is so delayed

that the excess of the inner coating, acting through the glass upon what surrounds it, attracts the opposite electricity towards the outer coating, so that it remains latent there, and the passage between the knobs of the spark micrometer is consequently hindered. This explanation serves also for the successive discharge at the striking distance.

§36. Heating of the connecting wire of the electrical battery.—For experiments on the heating of thin wires by the discharge of the battery, *Riess* used *Harris'* arrangement of an air thermometer, through the large globe of which the wire was stretched. The tube of the thermometer, narrow in comparison with the globe, was turned obliquely downwards and ended in a wider position, so that a small quantity of colored liquid there could penetrate the tube.

The scale of the thermometer was divided into lines. The instrument is represented in fig. 51.

Fig. 51.



The wire, and consequently the air in the globe, being heated by the discharge, the liquid in the tube is driven back. The depression of the column of liquid expressed in lines, is considered as the measure of the temperature.

A more precise description of this air thermometer will be given hereafter.

The results of an experimental series, with a platinum wire 0.0547 lines thick, are collected in the following table:

s.	2.	3.	4.	5.	6.
q.	h.	h.	h.	h.	h.
2	1.5				
3	4.3	3.	2.	1.5	
4	6.7	4.5	3.2	3.0	2.6
5	9.3	7.0	5.2	4.5	3.8
6	13.4	9.7	7.3	6.5	5.5
7		15.	11.0	8.8	7.3
8		17.5	14.1	11.3	9.3
9			17.8	14.3	11.7
10				16.7	14.3

h indicates the depression in the thermometer expressed in lines, q and s have their former signification.

If we assume that the depressions are proportional to the temperature of the wire used, and this will be proved further on, it appears, from these experiments, that the temperature is directly proportional to the square of the electrical density, but inversely to the magnitude of the surface of the battery, or that

$$h = n\frac{q^2}{s}$$

which is easily deduced from the above table.

The depression h being proportional to the square of the quantity q, with an equal number of jars, the quantity 8 must produce four times as great an effect as the quantity 4. We have for 3 jars $q = 8$, $h = 17.5$; $q = 4$, $h = 4.5$; then $\frac{17.5}{4.5} = 3.89$, or 4 nearly. For 4 jars, this quotient is $\frac{14.1}{3.2} = 4.4$; for 5 jars, $\frac{11.3}{3} = 3.77$; for 6 jars, $\frac{9.3}{3.9} = 3.57$. The mean of these quotients is 3.9 or very nearly 4.

Hence, the double quantity corresponds to the fourfold effect.

Comparing the effect which the quantity 3 produces with that of 9, we get for 4 jars the quotient $\frac{17.8}{2} = 8.9$; for 5 jars, $\frac{14.3}{1.5} = 9.53$; the mean is 9.4. The triple quantity then produces a ninefold depression.

Comparing in the same manner the other numbers of the table, we find that, with an equal number of jars on an average, h is proportional to the square of q.

The table also shows that the value of q being constant, h is inversely proportional to s; hence, if the same quantity of electricity be distributed over a double or triple surface, the depression is twice or thrice as small. The table, in the mean, gives this almost exactly.

For $s = 3$, $q = 4$, according to the above table, we have $h = 4.5$. Substituting this value in the above equation:

$$4.5 = n\ \frac{16}{3},$$

hence $n = 0.843$.

If in like manner we compute the value of the constant n from all the single observations, that is, from all the corresponding values of h, s, and q, of the above table, n is found as a mean to be equal to 0.88.

§ 37. INFLUENCE OF THE THICKNESS OF THE WIRE IN THE THERMOMETER.—The value of the constant n changes when another wire is placed in the globe of the thermometer. *Riess* repeated the experiments with wires of equal length, but of unequal thickness. Without presenting the entire table containing the data of these experiments, we shall consider only the final results.

For wires of the diameter:

0.119, 0.078, 0.0547, 0.05, 0.0225 lines he found for mean values of n,

0.18, 0.45, 0.88, 1.02, 2.69.

From the equation—

$$h = n \frac{q^2}{s}$$

it follows, that if experiments be made with the wires of equal length, but unequal thickness, using the same battery (or like values of s) with the same charge, (or constant value of q,) the depression h will be as the value of n corresponding to this thickness of wire. Comparing the above values of n with the corresponding diameter of the wire, we find that *cœteris paribus*, the value of n, and consequently the depression of the column of liquid, or the heating of the air in the globe of the air thermometer, is in proportion to the square of the corresponding radii of the wires.

Denoting the thickness of the above wires by 1, 2, 3, 4, and 5, the squares of the radii of the 4th and 1st are as 0.05^2 to 0.119^2, or as 0.0025 to 0.014169; but

$$\frac{0.014169}{0.0025} = 5.66.$$

the corresponding values of n are inversely as the square of their diameter; for

$$\frac{1.02}{0.18} = 5.66$$

If we divide the square of the diameter of the wire 1 in the series by the square of that of the other wires, the following quotients are found:

2.33, 4.73, 5.66, 28;

but dividing the value of n for the first wire in succession into the value of n for the 2d, 3d, &c., we get the following quotients:

2.5, 4.88, 5.66, 15,

which are very close to the above, excepting that in the case of the finest wire the quotients 28 and 15 differ considerably.

Disregarding this wire, it follows from the other experiments, that the values of the factor n, and consequently the depressions in the air thermometer, or the elevations of temperature of the air in the globe, are inversely as the square of the diameter of the wires; or in other words: *The increase of temperature of the air in the globe is, cœteris*

paribus, inversely proportional to the section of the wire; or expressed algebraically,

$$w = \frac{a. q^2}{r^2 s},$$

in which $\frac{a}{r^2}$ is substituted for n in the equation, and a represents a constant factor.

Hence, if a wire twice or thrice as thick be placed in the air thermometer, the temperature of the air in the globe will be four or nine times less than before the change.

The rise of temperature of the air in the globe is evidently proportional to the quantity of heat evolved in the wire; hence, having determined the temperature of the air, we learn the quantity of heat set free.

A wire twice, or three or four times as thick, has, for the same length, a mass four, nine or sixteen times as great; now if in the thick wires there is as much heat set free as in the thinner ones, the same quantity of heat has a greater mass to spread over, the elevation of the temperature is inversely as the mass, or, the square of the diameter, or algebraically,

$$\mathrm{T} = \gamma \frac{w}{r^2};$$

in which γ is a constant factor, and T indicates the temperature of the wire. From this follows the equation,

$$w = \frac{\mathrm{T}\, r^2}{\gamma};$$

if this value of w be substituted in the above equation, we have

$$\frac{\mathrm{T}\, r^2}{\gamma} = \frac{\alpha\, q^2}{r^2\, s},$$

hence

$$\mathrm{T} = \frac{\alpha\, \gamma}{r^4} \frac{q^2}{s} = \frac{\beta}{r^4} \frac{q^2}{s},$$

the interpretation of which is: *The elevation of the temperature of a wire, cæteris paribus, is inversely proportional to the fourth power of its diameter.* Hence, a wire two or three times as thick will occasion a rise of temperature sixteen or eighty-one times less, when perfectly equal charges of the same density are discharged through it, provided that the length of the wire is unchanged.

These relations hold good, of course, only when wires of the same substance are compared with each other, and as each substance has a different specific heat, for each one a different proportion will be found between the quantity of heat and the elevation of temperature.

In the experiments of *Riess* just described, platinum wires were used in the thermometer.

The last exceedingly fine wire did not accord with the law, which *Riess* explained by assuming, that the law is valid only for equal times of discharge, which may be considered equal as long as the diameter does not fall below a certain limit, but when this is the case,

the wire retards the discharge, and in consequence of this delay there is less elevation of temperature.

His first experiment showed him, that when the length of the wire in the globe was increased the temperature was somewhat lower.

§ 38. Influence of the length of the wire in the thermometer.— When the wire in the thermometer was made longer, a slight decrease in the heating was observed, which indicated a delay of the discharge. But when the closing wire of the circuit remained in all respects the same, and the temperature at different parts of it was examined, it appeared that the rise of temperature was independent of the length of the wire.

For instance, a piece of platinum wire in the air thermometer and another equally thick and double the length in *Henley's* discharger closing the circuit, a discharge of the battery produced a certain depression. The platinum wires being now exchanged, the one in the thermometer for that in the discharger, and inversely, the circuit evidently remains the same in length, the same discharge now produced a double depression. The double mass of platinum was in the thermometer in this case, and it had given off a double quantity of heat; hence, the temperature of the long platinum wire was the same as that of the short one.

We shall now consider more closely one of the experiments, by means of which *Riess* proved this. The radius of the wire in the thermometer was 0.036 lines; its length 59.7 lines. The diameter of the wire in the discharger was 0.058; its length 100.4 lines. A series of experiments were made with different numbers of jars and variable charges, which gave as their result

$$h = 0.91\frac{q^2}{s}.$$

The wires were then exchanged. A similar series gave the result

$$h = 0.56\frac{q^2}{s}.$$

If the wire last placed in the thermometer had been exactly as long as the other, the depressions, according to the previous paragraphs, should be as the square of the diameters; hence, the last case should give

$$h = 0.35\frac{q^2}{s}.$$

This coefficient of $\frac{q^2}{s}$ is to the coefficient 0.56, as 1 is to 1.6. But the length of the second wire is nearly in the same proportion, viz: in the proportion of 59.7 to 100.4, or 1 to 1.67 longer.

The depression in the second series, considering the different diameters, is greater in proportion to the increase of length of the wire; hence, the heating of the separate pieces of wire is independent of their length.

This can be shown better when the actual temperatures of the wire in the thermometer are computed. How this can be done will be

shown in § 43. For the first of the above described series of experiments the following temperature was obtained:

$$T' = 0.3975;$$

for the other,

$$T' = 0.0592.$$

These numbers are to each other as 1 to 6.66; the fourth powers of the corresponding diameters of the wires are as 1 to 6.738. The temperatures, consequently, are very nearly as the fourth powers of the diameters, and are independent of the length of the pieces of wire.

§ 39. INFLUENCE OF BREAKS IN THE WIRE UPON THE RISE OF TEMPERATURE.—A break in the closing wire has a marked influence upon the temperature. When the ends of the broken wire were pointed, the temperature was constantly lower than with an unbroken circuit, and the lower, the farther the points of the wire were apart. This is explained by the fact that the residual charge of the battery becomes greater as the distance the spark has to traverse is increased, and that consequently a less quantity of electricity passes through the wire than when there is no interruption.

Remarkable phenomena appeared when *Riess* applied to the ends of the wire two brass discs, 10.4 lines in diameter, which were kept parallel to each other. The following table presents a part of the results he obtained.

s.	*q.*	THE DISCS.		
		In contact.	0.1 line apart.	1 line apart.
		h.	*h.*	*h.*
3	3	4.8	4.7	5.3
	4	7.7	7.0	7.0
	5	11.0	10.9	10.3
	6	15.6	14.5	13.7
	4	6.0	6.0	7.3
	5	8.5	8.5	9.3
4	6	12.2	11.9	12.0
	7	15.6	15.5	14.6

For 0.1 line distance of the plates, the temperatures as a whole are less than when they are in contact, yet the difference is much less than might have been expected from the magnitude of the residual charge. At a greater distance of the plates, for which a greater residue remains, we are surprised to find temperatures sometimes even greater than in the case of contact of the plates; for weaker charges the temperature is greater at 1 line distance than when the plates are in contact; on the contrary, with more powerful charges, the contact of the discs produces a higher temperature.

Riess has clearly explained this in the following ingenious manner: The separation of the plates involves two conditions which act in opposite ways upon the temperature of the wire in the thermometer. One is the part of the electricity remaining in the battery—in consequence of which evidently the heating must be diminished. The other condition which, on the contrary, raises the temperature, requires a more extended explanation.

When the distance between the two discs is *less* than the striking distance of the battery, one spark passes between the knob of the battery and the knob of the discharger, and a second between the plates.

When the distance between the discs is *greater* than the striking distance, a spark can pass between the discs if the knob of the discharger is in contact with that of the battery. The passage of the spark between the plates is only possible because, generally, as we have seen above, (page 423) the striking distance between plates is greater than between knobs.

At the passage of the spark between discs, a condensation of electricity takes place at their edges, and this condensation, very probably, has an accelerating effect upon the discharge which shows itself by an increase of temperature.

This last condition, which raises the temperature of the closing wire, can appear only when the distance between the plates is greater than the striking distance between the knobs. Let the plates stand at a given distance. The striking distance between the knobs changes with the power of the charge; it is proportional to the fraction $\frac{q}{s}$; for weak charges it is small, for stronger charges it increases; hence, it is in weak charges only that the above mentioned acceleration of the discharge can increase the temperature so much that the opposite influence of the residual charge shall be overpowered.

In fact, we see in the above table that h, when the plates are 1 line apart, only when $s = 3$ and $q = 3$, $s = 4$ and $q = 4$, $s = 4$ and $q = 5$, is greater than h in the case of contact of the plates. In all these cases $\frac{q}{s}$ is not greater than 1.25. For charges so powerful that $\frac{q}{s}$ is greater than 1.25, the temperatures of the last column, as a whole, are less than the corresponding temperature in the case of contact of the plates.

If the separation of the plates is greater than the possible striking distance, of course there is no discharge.

The results were similar when small balls were used instead of plates, the striking distance between the small balls being a little greater than that between the large ones of the discharger and the battery; hence, in a favorable case, the temperature, at a distance of the small knobs of only 1 line, was very little higher than when they were in contact.

§ 40. Heating power of obstructed discharge.—When a thin insulator was introduced at the place of interruption, through which the discharge stroke could penetrate, the heating power was less, as

the resistance to be overcome was greater, as is shown by the following data.

The ends of the wire at the break were furnished with small knobs, (5.7 and 4.4 lines in diameter;) for $s=5$, $q=8$, and the separation of the knobs, 0.2 line, the result was as follows:

Substance between knobs.	Temperature.
Air..............	15.4
1 card...........	12.0
2 cards...........	8.0
Plate of mica......	4.9

The results were similar when metallic disks or points instead of knobs were used at the place of interruption.

Hence, the electrical discharge produces a temperature in the closing circuit as much less, as the resistance is greater, which has to be overcome before discharge can take place.

This is not a resistance which, as in the case of the interposition of a long conductor in the circuit, retards the discharge throughout its whole duration, but a resistance which renders discharge absolutely impossible so long as it exists.

The decrease of the heating power is always too great to be ascribed to the inconsiderable residue; hence we must draw the conclusion from the above experiments that an obstacle interposed at any place in the circuit being pierced by the discharge prolongs the duration of the discharge through all the rest of the circuit.

If the smallest possible charge be used for perforating mica, the hole is rarely made immediately at the spot where the connexion is interrupted; the electricity almost always passes along the plate of mica and penetrates at a place which, apparently, is less solid, in consequence of a crack. If the point of application of the conductors is not too far from the edge of the mica, the discharge takes place over the edge. The temperature in the thermometer is as much lower as the path the electricity has to traverse over the surface of the mica is greater.

The marks which the electricity leaves on the mica are very regnlar and delicate. *Riess* has examined these as well as the corresponding ones on glass.

§ 41. Marks left by electricity upon glass and mica.—*Riess* placed a glass plate, 0.37 of a line thick, carefully cleaned and warmed, (so that when tested by the electrometer it proved itself in all directions a perfect insulator,) between the points of the closing wire, from which the thermometer had been removed. The quantity of electricity, 15, collected in four jars discharged itself over the edge of the plate, which was $15\frac{1}{2}$ lines distant from the place where the points were placed, and left marks on both surfaces, from the points of contact to the edge.

The marks were faint and of one color; they grated when rubbed

with a smooth body, and under the microscope had the appearance of scratches on glass with rough sand. When tested by the electrometer, the points of contact being held between the fingers, it was found that the glass at the marked, as well as at several unmarked places, had become conducting. By breathing on the plate all the conducting places became visible, they remained unmoistened and showed more or less numerous ramifications; even after the glass plate had been washed with nitric acid and dried, the stripes appeared to conduct.

Other glass plates gave exactly similar results.

With mica the appearance of the electrical marks was quite different. A serpentine stripe, of uniform width, passed from the point of contact on both surfaces to the place of puncture, which, by transmitted light, was light gray in color, but in oblique reflected light appeared as a delicately colored band, bounded by two sharply defined dark lines, bordered by a clear brilliant fringe; the inner part of the band, between the fringe, contained blurred zones of yellow, blue, red and green colors.

The pieces of mica used in this experiment were good insulators both before and after use, though when breathed upon they appeared covered with innumerable reticulated ramifications, which were not moistened, indicating the places where the electricity had touched the surface.

There was no essential difference between the two surfaces of the plate of mica, either in regard to the colored stripes, or the reticulated figures.

The electricity appeared to penetrate only by a sort of crack into the substance of the glass, and even to separate the alkali, which was indicated by the circumstance, that the injured places became more perceptible after a while, than immediately after the experiment.

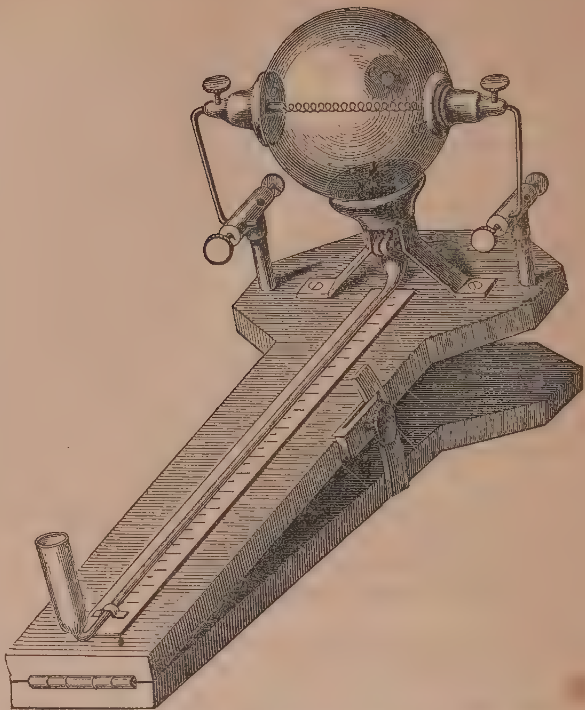
A plate of mica having been smeared with oil, a discharge, which without the oil would have produced colored stripes, penetrated it at the place of contact. An irregular hole appeared with fused edges, about which there was a slight splitting of the mica.

By careful diminution of the electrical accumulation, *Riess* obtained repeatedly, in spite of the coating of the oil, discharges without penetrating, and colored stripes of considerable length and size towards the edge of the plate, or towards a previously pierced place, which seemed to indicate that the mica conducts electricity better in the direction of its lamina than perpendicular to them.

In general the electrical marks on glass and mica are altogether dissimilar, though there are kinds of glass which, at their surface conduct electricity quite well, on which stripes appear similar to those on mica.

§ 42. The air thermometer.—The air thermoneter, which *Riess* used in his researches, is represented in fig. 53, from an instrument made by *Kleiner* of Berlin.

Fig. 53.



Riess gives a description of his instrument in several places in his memoirs and in *Dove's Repertorium.* But the description is nowhere perfectly clear and sufficiently illustrated by figures. Indeed, it is much to be wished that authors generally would give better drawings of their apparatus, by means of which tedious and yet insufficient descriptions would be avoided.

Fig. 53 represents the instrument $\frac{1}{4}$ its natural size. The globe which is about 3 inches in diameter, is perforated in three places. The openings at *a* and *b* are diametrically opposite each other and are provided with perforated metallic pieces, between which the platinum wire is extended ; the third opening *c* is likewise furnished with a metallic fitting, the opening of which is closed by a stopper, so that before the experiment the air inside the globe can be put in equilibrium with the external atmosphere.

The wire is arranged as shown in figs. 54 and 55.

Fig. 54.

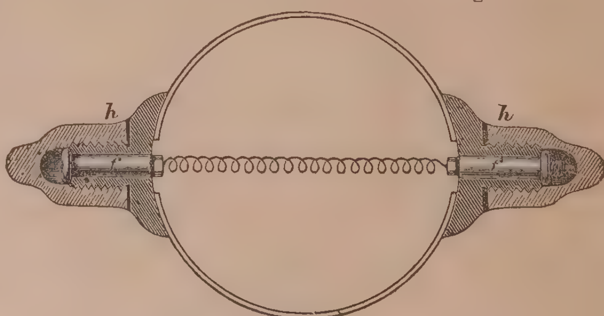


Fig. 55.

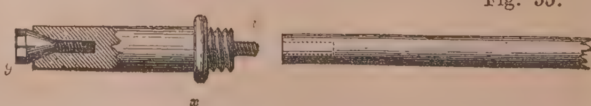


Fig. 54 represents a section of the globe $\frac{1}{2}$ the natural size, passing through the middle of the openings *a* and *b*. The fixtures cemented to these openings have holes about 2 lines in diameter through which the cylinder *f* passes. This has a conical cavity on the end towards the inside of the globe, into

which the metallic cone g with a split head is screwed, as is more clearly shown in fig. 55. In the slit the platinum wire is held and is firmly clamped by screwing the cone in deeper. *Riess* terms this contrivance a "cone clamp."

When one wire is to be taken out in order to introduce another one, the method pursued is as follows: The cap h is first unscrewed; the cylinder f, of one of the sides, is lengthened externally by a screw, to which another of less diameter is attached. On this last, as shown in Fig. 55, is fastened a rod, whose length is greater than the diameter of the globe together with the metallic attachments; when this is done, the metallic plate x, which prevents the cylinder f from being drawn into the globe, can be detached and slipped on the rod. It is now easy to draw the cylinder f from the left side of the globe, and push the rod, with its attached cylinder, on the other side after it; the wire may then be removed and another put between the cone clamps. To replace the cylinder, the rod is first passed through the globe drawing f with it, the plate x is screwed into its place, and the rod being removed, the two caps h are again screwed on.

The air thermometers, constructed by *Kleiner*, are very beautiful and well made, but their price (25 thalers and 2 thalers for packing) is high. It is greatly to be desired, on this account, that the instrument should have a simpler construction, which would render it less costly.

The inclination of the tube, as seen in Fig. 53, can be changed at pleasure, and then the sensibility of the instrument increased to any desired degree. *Riess* used generally an inclination of $6\frac{1}{2}$ degrees to the horizon.

The scale of the tube is divided into lines. All the other parts are clearly shown in the figure.

The capacity of the globe of *Riess'* instrument was 40,766 cubic lines. The size of the tube was such that, the space between two division lines being taken as unity, the globe contained 320,307 such units of capacity.

§43. THEORY OF THE INSTRUMENT.—When the air in the globe is heated, the column of liquid is depressed; thus, on the one hand, the tension of the air, and, on the other, its volume, is increased.

But the increase of tension, as well as that of volume, is proportional to the rise of temperature; hence the sum of both effects, or *the depression, is proportional to the rise of temperature.*

We will now compute the increase of the temperature of the air in the globe, which produces a depression of one line.

Suppose the temperature to be 15° Cent. and the barometer to indicate 336 lines.

The liquid in the tube was 15 times lighter than mercury; hence a barometer of this liquid would have a height of $15 \times 336 = 5040$ lines.

But the tube is not in a vertical position, it is 6°.5 to the horizon. The column of liquid in a tube thus inclined must have the length

$$\frac{5040}{\sin 6^\circ.5} = \frac{5040}{0.113} = 44.600 \text{ lines,}$$

in order to be in equilibrium with the pressure of the air; hence we can consider 44,600 as the measure of the tension of the air in the globe.

The temperature of the air being increased 1° (to 16°) it dilates in the proportion:

$$(1 + 15 \times 0.00365) \text{ to } (1 + 16 \times 0.00365),$$
$$1.05475 \text{ to } 1.05840,$$
$$1 \text{ to } 1.00346;$$

the air of 15° consequently dilates 0.00346 of its volume for each degree of temperature above 15°.

But if the air cannot dilate, its tension increases in the same proportion, hence we have

$$1 : 1.00346 = 44{,}600''' : 44{,}754.$$

Thus a rise of temperature of 1° produces a depression of 154 lines in the tube, provided no increase of volume takes place; a depression of 1 line, therefore, corresponds to a rise of temperature of $\frac{1}{154} = 0°.00649$ when the increase of tension alone is considered.

The capacity of the globe amounts to 320,307 units of division of the tube. A rise of temperature from 15° to 16° would expand the air in the globe 1108 such units, if the air could expand freely; hence an increase in volume of 1 line in the tube corresponds to a rise of temperature of $\frac{1}{1108} = 0°.0009$.

A depression of 1 line, considering the increase of tension and of volume, corresponds to a temperature

$$0°.00649 + 0°.0009 = 0°.0074.$$

From the elevation of temperature of the air in the globe, that of the wire can be found. Let t be the temperature of the air and of the wire before discharge; T the temperature of the wire after the discharge; t' the rise of temperature which the wire causes by imparting its excess of heat to the air; then

$$\mathrm{M\,C}\,(\mathrm{T} - t') = m\,c\,(t' - t),$$

M representing the mass and C the specific heat of the platinum wire, m the mass and c the specific heat of the air in the globe. From this equation we get

$$\mathrm{T} - t = (t' - t)\,\frac{m\,c + \mathrm{M\,C}}{\mathrm{M\,C}}$$

or

$$\mathrm{T}' = (t' - t)\left(1 + \frac{m\,c}{\mathrm{M\,C}}\right) = 0.0074\,h\left(1 + \frac{m\,c}{\mathrm{M\,C}}\right),$$

T′ indicating the rise of temperature of the wire, $t' - t$ is the rise of temperature of the air, which can be computed easily from the observed depression.

The capacity of the globe is 40766 cubic lines; the specific gravity of the air, at 15°, is 0.00114, the specific heat of the air 0.188; we have, therefore,

$$\mathrm{T}' = (0.0074.\,h)\left(1 + \frac{40766 \times 0.00114 \times 0.188}{3.14\,.\,l\,.\,r^2\,.\,21 \times 0.031}\right),$$

factor 0.0070 would have been substituted for 0.0074, or a factor which is less in the proportion of 1 to 1.0571; on the contrary, m, the value of the expression in the brackets, (since 1 to $\frac{m\,c}{\mathrm{M\,C}}$ is very small,) would become greater in the proportion of 1 : 1.0547. Thus the one factor would increase in almost exactly the same proportion in which the other decreased, and the value of T′ would remain almost without change; hence it follows that slight fluctuations in the temperature of the surrounding air may be totally disregarded, and no correction of the value of T′ computed for 15° is necessary.

A similar discussion of the height of the barometer leads to the same result—that is to say, although our formula is computed for a height of 336 lines, it may be used for other heights, because the intermediate fluctuations of the barometer have no marked influence on the value of T′.

§ 44. INFLUENCE OF THE LENGTH OF THE CONNECTING WIRE ON ITS RISE OF TEMPERATURE.—We have seen above that, when the same discharge passes through a series of wires introduced into the circuit together, the heating of the separate pieces is, independent of their length, and inversely proportional to the fourth power of their semi-diameters.

But as soon as the circuit is considerably prolonged, by the introduction of new wires, the heat in all parts of the circuit decreases

In order to investigate the influence of an increase of length in the circuit, *Riess* interposed, in succession, pieces of the same copper wire of different lengths, by means of *Henley's* discharger, retaining in the thermometer the same platinum wire. With each piece an experimental series of the same kind was made, as shown on page 426. Indicating the length of the interposed copper wire (its thickness being 0.29 lines) by λ.

$$\text{For } \lambda = 0 \quad , \quad h = 0.78\,\frac{q^2}{s}$$

$$\text{“} \quad \lambda = 9.6^{\text{feet}},\ h = 0.69\,\frac{q^2}{s}$$

$$\text{“} \quad \lambda = 49.0^{\text{ft}}.,\ h = 0.48\,\frac{q^2}{s}$$

$$\text{“} \quad \lambda = 98.4^{\text{ft}}.,\ h = 0.34\,\frac{q^2}{s}$$

$$\text{“} \quad \lambda = 147.7^{\text{ft}}.,\ h = 0.27\,\frac{q^2}{s}$$

$$\text{“} \quad \lambda = 246.4^{\text{ft}}.,\ h = 0.21\,\frac{q}{s}$$

We see from these data that the heating constantly decreases as the wires increase in length, the value of $\frac{q^2}{s}$ being constant.

The values of h are evidently proportional to the co-efficients of $\frac{q^2}{s}$. For $\frac{q^2}{s} = 1$ we have the following relation between h and λ:

$$h = \frac{0.78}{1 + 0.013\,\lambda} \quad \ldots\ldots (1)$$

For $\lambda = 0$, this equation gives $h = 0.78$; for $\lambda = 49$ it gives $h = 0.476$; for $\lambda = 147.7$, $h = 0.267$, &c., all of which values correspond *remarkably* well with the above observations, so that we can consider this equation as the expression of the actual relation between h and λ.

Dividing the numerator and denominator of this equation by 0.013, we get

$$h = \frac{60}{76.9 + \lambda}.$$

In this form we find the greatest resemblance to the law of *Ohm*. The discharge in these experiments had, in addition to the variable length λ of the interposed copper wire, to traverse the invariable part of the circuit, in which the platinum wire of the thermometer was comprised.

Each increase of length in the circuit resists the rise of temperature, which is, in fact, inversely proportional to the length of the circuit, as shown by the formula, if we assume that the constant part of the circuit acts like a piece of copper wire 76.9 feet long and having the thickness of the interposed wire.

The above value of h represents only a special case; it may be generalized thus:

$$h = \frac{\frac{a}{b}}{\frac{1}{b} + \lambda} \frac{q^2}{s} = \frac{a'}{\mathrm{L} + \lambda}$$

by substituting a' for $\frac{a}{b}$, and L for $\frac{1}{b}$. Thus we have the same law here for the development of heat as for the magnetic effect of the galvanic battery.

Evidently L here expresses the reduced length of the circuit; that is, it indicates how long a platinum wire should be, of the same thickness as the interposed wire whose length is λ, to give the same value of retardation as the whole circuit, with the exception of the platinum wire in the discharger having the length λ.

This last transformation, by means of which *Riess'* law of heating gives a form perfectly similar to *Ohm's* law, *Riess* has not presented with his formula. In the beginning of his memoir he merely made the general remark that the similarity of his results to the magnetic effect of the galvanic battery was not to be overlooked, but without presenting or proving it; indeed, in his treatise he has intentionally, as he says, avoided representations which might seem to refer to galvanism, because the subject of electricity needs well founded experiments more than theoretical disquisitions and analogies.

Equation (1) brought into the general form is as follows:

$$h = \frac{a}{1 + b\lambda}$$

from which *Riess* draws the following conclusion:

By lengthening the circuit the rise of temperature is diminished. If, instead of metallic wire, a piece of moistened wood, or a glass tube filled with water, be introduced, the most powerful charges of the battery are not able to produce a depression of even 0.1 line. Here the discharge of the battery is no longer instantaneous, as with the interposition of the longest copper wire; it requires a perceptible time. Hence it is inferred that a difference might be observed in the time of discharge when a long or short wire was used if we were endowed with keener senses. The heating of the platinum wire in the thermometer appears to be in simple inverse ratio with the time during which the discharge lasts. A temperature a being observed, while a certain quantity of electricity of a given density is discharged in the time 1, the time of discharge will be prolonged by $b\,\lambda$, if a wire of the length λ is introduced; and the temperature is now

$$h = \frac{a}{1 + b\,\lambda}$$

or *the heating of a wire by the discharge of an electrical battery is inversely proportional to the duration of the discharge; the duration of the discharge is prolonged by lengthening the wire of the circuit by a time which is proportional to the length of the wire added.*

§ 45. Influence of the thickness of the connecting wire upon its temperature.—In order to investigate the influence of the thickness of the connecting wire *Riess* removed the interposed copper wire which he had used in the previous experiments, and in its stead placed, in succession, platinum wires of various dimensions between the arms of *Henley's* discharger. The result was that the thermometer indicated temperatures as much lower, as the platinum wires of like lengths were thinner. The data thus obtained admit of the formula

$$T = \frac{a}{1 + \frac{b\,\lambda}{s^2}}\;\frac{q^2}{s}$$

in which s represents the radius of the wire. Expressed in words this means:

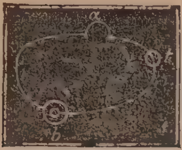
The heating of a wire by electrical discharge is inversely proportional to the duration of the discharge; by interposing homogenous wires the discharge is prolonged by a time which is directly proportional to the length of the interposed wire, and inversely proportional to its section.

§ 46. Temperature in the main conductor of a branched circuit. Having determined how much retardation of discharge is produced by a wire a introduced into the circuit, the value of retardation by a second wire β is obtained in like manner; and it may be asked now how much retardation is produced by introducing both wires at the same time as branches in the circuit.

The annexed diagrams may serve to show more clearly how this question is to be understood.

In figure 56 b represents the battery, t the air thermometer, a a piece of wire introduced into the circuit.

Fig. 56.



In the two following figures b and t represent the same things as in the other; but in figure 57 we have the wire β instead of a, and in figure 58 both pieces of wire are introduced together, so as to form branches.

Fig. 58.

If, now, for a given charge of the battery a certain temperature of the air thermometer is produced by the combination in figures 56 and 57, the question is, what is the temperature for the same charge with the combination of figure 58?

Fig. 57.

Riess has treated this question in the 63d vol., page 486, of *Poggendorf's Annalen.*

As we have just seen, the elevation of temperature by the air thermometer for unity of charge is represented by the formula—

$$h = \frac{a}{1+z}$$

a indicating the temperature which occurs when only the constant parts of the conducting circle close the battery, z the time the discharge is retarded by interposing any piece of wire in the circuit, provided the time in which the battery is discharged when the said wire is out of the circuit is taken as unity.

Having determined by experiment the value of retardation, z for one wire a introduced into the conducting circle, and then, in the same manner, the value z^1 for a second wire β, we are able to deduce theoretically the values of retardation when both wires are introduced together, as shown in figure 58.

The wire a discharges the unit of electrical charge in the time z; in the unit of time, therefore, it can discharge the quantity $\frac{1}{z}$.

In like manner the second wire β in the unit of time can discharge the quantity of electricity $\frac{1}{z'}$.

In the unit of time, then, the two wires introduced together (figure 58) into the conducting circle can discharge the quantity $\frac{1}{z} + \frac{1}{z'}$.

Hence it follows that with the combination of figure 58 the two wires can discharge the quantity of electricity 1 in the time

$$\frac{1}{\frac{1}{z} + \frac{1}{z'}}$$

Now, if—

$$h = \frac{a}{1+z} \, \frac{q^2}{s}$$

is the rise of temperature in the thermometer when the wire α is in the circuit, and if—

$$h' = \frac{a}{1+z'} \cdot \frac{q^2}{s}$$

represents the temperature in the thermometer when the wire β is introduced, the charge being the same, we have—

$$h'' = \frac{a}{1+\cfrac{1}{\cfrac{1}{z}+\cfrac{1}{z'}}} \cdot \frac{q^2}{s}$$

for the rise of temperature, when the wires α and β are introduced at the same time, forming branches as represented in Fig. 58.

In accordance with the same train of reasoning it follows that, if the values of retardation of three wires are z, z', z'', and they be introduced into the circuit at the same time, the retardation of the whole system will be

$$\frac{1}{\cfrac{1}{z}+\cfrac{1}{z'}+\cfrac{1}{z''}}$$

The correctness of this deduction *Riess* has proved by numerous experiments, a few of which I shall present.

The battery used in all these experiments consisted of four jars, with 2.6 square feet of inner coating. Between the constant portions of the circuit a series of platinum wires were inserted, varying in length, but uniform in thickness; through each wire various quantities of electricity were discharged, and from the combination of these experiments the value of a of the above equation was found = 1,232. The manner in which a can be determined from the combination of numerous experiments is shown at page 426.

A platinum wire α (whose dimensions it is not necessary here to know) being introduced, and various quantities of electricity discharged, the experiments gave for the unit of charge $h = 0.81$, hence

$$0.81 = \frac{1.232}{1+z};$$

consequently $z = 0.5209$ and $\frac{1}{z} = 1.919$; the wire β being substituted for α, gave for the unit of charge $h = 0.94$; hence $z' = 0.3107$, and $\frac{1}{z} = 3.219$.

The two wires α and β being introduced together as two branches of the circuit, we have, according to our deduction, for the heat developed in the main conductor—

$$h = \frac{1.231}{1+\cfrac{1}{1.919+3.219}} = \frac{1.231}{1+\cfrac{1}{5.138}} = 1.031.$$

The experiment gave $h = 1.03$.

Closing the circuit with a branch α', the result was

$$h = 0.386, \text{ and } \frac{1}{z} = 0.4563.$$

Closing with a branch β',

$$h = 0.519, \text{ and } \frac{1}{z'} = 0.7279.$$

Closing with an (iron) wire γ',

$$h = 0.449, \text{ and } \frac{1}{z''} = 0.5734.$$

Therefore—

$$\frac{1}{z} + \frac{1}{z'} + \frac{1}{z''} = 1.758\,;$$

from which it follows that, when the circuit is closed with the three branches simultaneously, we get for the temperature with unit of charge,

$$h = \frac{1.232}{1 + \frac{1}{1.758}} = 0.7851.$$

The experiment gave for this combination,

$$h = 0.784.$$

Additional experiments showed a like harmony between the computed and observed values.

§ 47. TEMPERATURE IN A BRANCH OF THE CONDUCTING CIRCUIT.—We have seen that the quantity of electricity q is discharged through two branches of the closed circuit in the time $\frac{1}{\frac{1}{z} + \frac{1}{z'}}$; z and z' representing the time in which each of the two branches is able separately to discharge the same quantity of electricity. In the unit of time the first branch can discharge the quantity of electricity $\frac{q}{z}$; hence the quantity of electricity which the first branch discharges in the time $\frac{1}{\frac{1}{z} + \frac{1}{z'}}$, equals $\frac{q}{z\left(\frac{1}{z} + \frac{1}{z'}\right)}$; likewise the second branch discharges in the same time the quantity $\frac{q}{z'\left(\frac{1}{z} + \frac{1}{z'}\right)}$. Hence the temperature

$$h_n = \frac{a}{1 + \frac{1}{\frac{1}{z} + \frac{1}{z'}}} \cdot \frac{q^2}{s.z^2\left(\frac{1}{z} + \frac{1}{z'}\right)^2}$$

$$= \frac{a}{\left(\frac{1}{z}+\frac{1}{z'}\right)\left(1+\frac{1}{z}+\frac{1}{z'}\right)z^2} \cdot \frac{q^2}{s}.$$

Riess found this formula also confirmed by his experiments.

To introduce an air thermometer into the branches without changing the circuit in other respects, platinum wires were placed in the branches with the same connecting pieces, and of equal length and thickness with the platinum wire in the thermometer, so that these pieces of wire could be removed from the branches and the thermometer substituted for them; the place in the circuit where the thermometer stood was occupied by a connecting wire of equal dimensions.

In all these experiments the branches were very short, and it is for such cases only that the above formulas are applicable. When the branches are long, each induces in the other lateral currents in the same direction. But if the main current in α induces a lateral current in β, α completes, as it were, the circuit for the lateral current β; the lateral current excited in β will thus traverse α in a direction opposite to that of the main current; to this is to be added the lateral current excited in α by β. The effect of these lateral currents is shown not only in the branches, but they modify the main current in the general conductor. These exceedingly complicated disturbances of the discharge current in a branched wire are difficult, as *Riess* has justly remarked, to bring under a generally valid law.

§ 48. ELECTRICAL RETARDING POWER OF METALS.—*Riess* concludes the investigation just described by an account of his highly interesting and important labors on the electrical retarding power of metals.

We have seen that a wire brought into the circuit by means of *Henley's* discharger retards the discharge, and that in consequence of this retardation the depression of the air thermometer diminishes.

The wire in the thermometer remaining unchanged, if we introduce first a platinum wire, and afterwards one of copper of equal length and thickness into the circuit, an equal depression will not be obtained; whence it follows that these wires, though they have the same dimensions, do not retard the electrical discharge in a like measure; hence *the retarding force* of the two metals is specifically different.

With a copper wire a greater depression will be obtained than with a platinum wire of equal length and thickness; the copper, therefore, retards the electrical charge less than the platinum wire.

For discussion and computation of the retarding power of different metals, the following is the simplest method to be pursued: First place a platinum wire in the discharger and determine the depression produced by a given charge of the battery. Introduce another wire instead of the platinum, (having the same thickness,) and lengthen or shorten it until the same charge of the battery produces the same effect. The retarding forces are to each other inversely as the length of the wires used.

A copper wire, for instance, has to be 6.44 times as long as a platinum wire of the same thickness to effect an equal retardation ; hence the retarding force of platinum is 6.44 times as great as that of copper. Making the retarding force of platinum equal to 1, we find that of copper to be 0.1552.

This would be, as I have said, the simplest method for discussion and computation. The prosecution of the experiments, however, would be very troublesome. On this account, *Riess* has preferred to make the experiments with wires of determinate length and thickness, observing the corresponding depressions, and from these he computed the retarding force by the aid of the law found above.

In the following experiments the same platinum wire (59.25 lines long and 0.04098 lines in diameter) was retained in the thermometer. A platinum wire of the same thickness, but 34.67 lines long, was placed in the discharger. A series of experiments instituted according to the method described above, q and s varying, and the corresponding depression being observed, gave as the result

$$h = 1.37 \frac{q^2}{s};$$

a platinum wire of the same thickness, but 87.62 lines long, gave

$$h = 1.01 \frac{q^2}{s};$$

a third platinum wire, equal in thickness but 143.5 lines in length, gave

$$h = 0.79 \frac{q^2}{s}.$$

The coefficient of $\frac{q^2}{s}$ has, as we have seen above, (page 440,) the form

$$\frac{a}{1 + b\lambda'};$$

to determine the constants a and b, two series of observations are necessary, that is, two numerical values of these factors must be known, corresponding to two different lengths of λ.

First, we have

$$\frac{a}{1 + b \,.\, 34.67} = 1.37$$

then

$$\frac{a}{1 + b \,.\, 87.62} = 1.01;$$

combining these two equations we get

$$a = 1.787, \quad b = 0.00878.$$

Combining, in like manner, the first and third series of observations, we find

$$a = 1.788, \quad b = 0.008807;$$

combining the second and third series, we get

$$a = 1.792, \quad b = 0.008843.$$

The mean of these three results is

$$a = 1.789, \quad b = 0.008810.$$

To determine the retarding force of copper, a wire of this metal was placed in the discharger. Its length was 141.6 lines, its radius 0.041952 line. Assuming the thickness of the platinum wire, previously examined, as unity, the value of the semi-diameter of the copper wirewas

$$\rho = 1.0236.$$

A series of experiments with this wire gave

$$h = 1.51 \frac{q^2}{s}.$$

But, according to the above, we have the coefficient

$$1.51 = \frac{a}{1 + \frac{b' \lambda}{\rho^2}},$$

in which a equals the value just found, 1.789, $\lambda = 141.6$, and $\rho = 1.0236$. From this we find for b' the value

$$b' = 0.001367.$$

Dividing this value by the value of b found for platinum, we get

$$\frac{b'}{b} = 0.1552;$$

that is, the retarding force of copper is 0.155 times as great as that of platinum; or, taking the retarding force of platinum for unity, that of copper is 0.1552.

In like manner *Riess* determined the retarding force of other metals and found as follows:

Metals.	Retarding force.	Inverse value of retarding force; copper = 100.
Silver	0. 1043	148. 74
Copper	0. 1552	100. 00
Gold	0. 1746	88. 87
Cadmium	0. 4047	38. 35
Brass	0. 5602	27. 70
Palladium	0. 8535	18. 18
Iron	0. 8789	17. 66
Platinum	1. 0000	15. 52
Tin	1. 053	14. 70
Nickel	1. 180	13. 15
Lead	1. 503	10. 32
German silver	1. 752	8. 86

The first column of figures gives the proportion in which wires of the same dimensions, but of different substances, retard the discharge of the electrica :oattery. The inverse values of the retarding forces

in the second column correspond to what physicists are accustomed to call the *conductive capacity*.

§ 49. CAPACITY OF METALS FOR THE DEVELOPMENT OF HEAT.—When a platinum wire 59.25 lines long, and 0.04098 lines in radius was in the thermometer, and a copper wire 141.6 lines long, 0.041952 lines radius, in the discharger a series of observations gave

$$h = 1.51 \frac{q^2}{s}.$$

In these experiments a thermometer was used whose globe contained 22.668 cubic lines, which in parts of the scale amounted to 188,404. Hence a depression of 1 line, as shown in § 43 corresponds to a rise of temperature of the air of 0°.00802. The rise of temperature of the wire was found, as there shown, by the formula

$$T = 0.00802\, h \left(1 + \frac{m\,c}{M\,C}\right)$$

The computation being performed we get, with $\frac{q^2}{s} = 1$, for the rise of temperature in the platinum wire,

$$0^\circ.4635.$$

The wires being exchanged, so that the copper wire was in the thermometer while the platinum was in the discharger, the result was

$$h = 0.46 \frac{q^2}{s};$$

and therefore, with $\frac{q^2}{s} = 1$, the rise of temperature of the copper wire is

$$0^\circ.04678.$$

Thus the same discharge produces in the two wires very unequal temperatures. It is true that the thickness of the wires was not the same, the radius of the platinum being 0.04098 lines, that of the copper 0.04195 lines, but as shown above, the rise of temperature in the wires being *cœteris paribus* as the fourth powers of the radii, a platinum wire, therefore, with the same dimensions as the copper wire, would give an increase of temperature of

$$0.4635 \frac{0.04098^4}{0.04195^4} = 0^\circ.4230.$$

Thus the same discharge produces, in wires of platinum and copper of like dimensions, increases of temperature which are to each other as 0.4230 to 0.04678; hence the same discharge produces in a copper wire a rise of temperature $\frac{0.04678}{0.4230} = 0.1106$ times as great as in an equally thick platinum wire; or copper has a *capacity for the development of heat* 0.1106 times as great as platinum.

Riess found by his formula 0.1133 instead of 0.1106—a difference so small as not to require further examination.

In a similar manner he determined the heating capacity of other metals, and found as follows:

Metal.	Heating capacity.	Quantity of heat.
Silver	0.1267	0.1126
Copper	0.1133	0.1447
Gold	0.2112	0.1847
Brass	0.3861	0.5616
Iron	0.7080	0.9148
Platinum	1.0000	1.0000
Tin	1.570	0.8917
Nickel	0.8727	1.182
Lead	2.876	1.455

The first of these columns of numbers gives the capacity of metals for the development of heat—that is, the relative height of temperature different kinds of wire of the same thickness would reach, if they were fastened together end to end, and an electric battery discharged through them.

Multiplying the heating capacities of metals by their specific weights and specific heats, the numbers are obtained, which show the quantities of heat set free by the same discharge in equally thick wires.

Again, taking platinum for unity, we must divide all the products found by the specific weight and specific heat of platinum. In this manner the numbers of the second column were obtained.

This series of numbers shows the ratio of the quantities of heat set free in different kinds of wires of equal diameters when, being fastened end to end, they discharge an electrical battery.

Comparing these numbers with the retarding forces given on page 446 we see that they are almost precisely equal, the difference being so small as to be explained by the fluctuating values of capacity for heat and specific weights in connexion with errors of observation; *hence, the retarding force of different metals is (cœteris paribus) in the same proportion as the quantity of heat set free in the wires by the electrical discharge.*

Hence it follows further, that the relative electrical heating capacity of a metal may be found by dividing its electrical retarding force by its specific weight and capacity for heat; multiplying by the specific weight and capacity for heat of platinum, when the heating capacity of platinum is = 1.

§ 50. Entire quantity of heat produced by the discharge.—*Vorsselman de Heer* made use of the experiments given above for determining the entire quantity of heat which an electrical dischager generates (Pog. Ann. XLVIII, 292), by making in *Riess'* formula a transformation which is in perfect harmony with the modification given in page 439.

He showed in this way what should be the length L of a platinum wire of given thickness which should offer to the discharge the same

resistance; or, in other words, which should produce the same retardation of the discharge as that caused by the constant part of the conducting circuit.

Since the quantity of heat set free in a piece of wire is proportional to its retarding force, and since, moreover, the heating of a given wire in any part of the circuit can be determined by aid of the electrical air thermometer, we can compute the quantity of heat set free in the whole circuit, were it to consist of a single wire of the length $L + \lambda$ and of a given thickness. *Vorsselmann de Heer* assumes that in the whole circuit a quantity of heat, exactly equal to that computed, is actually set free, because the circuit has the same retarding force as the computed length of wire, and the heat set free is proportional to the retardation.

Riess, however, protests against this conclusion, (Pog. Ann. XLVIII, 320,) and with justice replies that the greatest part of the retardation in the conducting circuit is due not so much to the continuous metallic parts themselves as to the places at which they are joined; and that experiment gives us information as to the relation between the retarding force and development of heat for continuous wires only, but not for discontinuous wires when joined together; that as yet we know nothing of the relation between the retarding force and heating at the joints.

§ 51. Ignition and fusion of metallic wires by electrical discharges.—While feeble currents, discharged through thin wires, produce changes of temperature, the laws of which *Riess* has thoroughly studied, and with which we have hitherto been engaged, more powerful discharges bring the wires into a state of ignition and even of fusion.

The question now is, whether these effects, namely, the ignition and fusion of wires, can be explained by the increase of heat according to the laws found for lower temperatures or not.

Riess has accurately investigated the ignition and fusion of metallic wires by electricity, (Pog. Ann. LXV, 481,) and shows that this is not the case.

When a thin platinum wire 15 lines long, together with a thicker one in the air thermometer, were introduced into the conducting circuit of a battery, observations with feeble discharges gave, according to the above laws for units of charge, a rise of temperature in the thin wire of $0^\circ.68$.

By discharging the quantity of electricity, 42 in 5 jars, the wire was completely melted. Computing the rise of temperature in the thin wire for this charge, according to the known laws, we get

$$0.68 42 \tfrac{2}{5} = 245^\circ.$$

This temperature is not high enough for the ignition, far less for the fusion of platinum; hence, it is clear that the temperature of 245° which was computed according to the laws obtained for weak charges, is not that to which the platinum really reaches when melted by electricity.

From this it follows that a powerful charge acts in a different manner upon the wire than a weak one; and it also appears that a powerful discharge produces mechanical effects in the wire, which are not at all shown by weaker discharges.

Riess has very carefully investigated the effects of gradually increasing discharges. To produce very powerful effects he used a battery of 7 jars, with a coating of 2.6 square feet to each jar.

Long before the quantity of electricity required for ignition had been reached, the wires showed appearances which evinced a forcible penetration of the electricity; the wire was visibly shaken, small sparks were given off at its ends, particles of its surface were thrown off, rising in the form of a dense vapor. It often happened that the throwing off of larger pieces of glowing metal occurred with the passage of the spark, giving to it a scintillating appearance. Charges still more powerful produced bends in the wire, which appeared exactly as though they had been made by an edged tool. We shall give here only one experimental series, showing these phenomena. A platinum wire of 0.0261 line semi-diameter, and 16 lines long, appeared as follows:

No. of jars.	Quantity of electricity.	Phenomena
4	6	Sparks on the inner part of the wire; that is, nearest the inner coating.
	8	Streaks of vapor over the whole wire.
	9	Vapor sparks on the outer part.
	10	The same.
	11	Neither sparks nor vapor; strong bending.
	12	Sparks on outer end; bending increased.
	13	Wire ignited.

All the phenomena preceding ignition appeared more readily when the wire was not stretched.

Earlier observers had already noticed a shortening of wires ignited by electrical discharges, which shortening is now explained by the bending mentioned above.

The sparks spoken of as seen at the ends of the wire depend upon the material of the wire, and upon that of the clamp. The scintillating sparks appear in great quantity with iron wire, while with copper none were observed.

Far more constant than the appearance of sparks is the formation of the vapor which is seen with every metal. The facility with which it is formed, with different metals is the same as for different wires of the same metal. Its formation is promoted by a great number of furrows left by the draw-plate upon the wire; and *Riess* has found that it is diminished by carefully polishing the wire.

§ 52. Laws of electrical ignition.

1. *Ignition in proportion to amount of charge.*—A thin platinum wire of 0.116 line diameter, and 26.6 lines length, together with an electrical thermometer containing a platinum wire so thick as to remain uninjured by the strongest discharge, were introduced into the conducting circuit. A given number of jars were charged with increasing quantities of electricity until a quantity was attained which produced

ignition in the wire, visible by daylight, the thermometer being observed each time. The same was repeated with different number of jars. Such a series of observations gave the following charges required to produce ignition with the corresponding depressions of the thermometer.

No. of jars.	Quantity of electricity.	Temp. of ther.
5	12	20.2
4	11	21.8
3	10	21.6
2	8	20.3

To bring the thin wire to a visible red heat, the quantities of electricity 12 in 5 jars, 11 in 4, 10 in 3, and 8 in 2, were necessary. Dividing the square of the quantities of electricity by the corresponding number of jars, we get the following quotients:

$$144.5 = 28.5,\ 121.4 = 30.2,\ 100.3 = 33.3,\ 64.2 = 32.$$

These quotients are very nearly equal, and from this we may infer that, if a quantity of electricity q in s jars make a wire red hot, under circumstances equal in other respects, the quantity q' in s' jars will produce the the same effect if $\frac{q^2}{s} = \frac{q'^2}{s'}$. In the above experiments the mean of the quotients is 31; hence, for

jars	2,	3,	4,	5,	6,	7
the quantities of E	7.9,	9.6,	11,	12.4,	13.6,	14.7

will be found as those required to produce incandescence in the above mentioned wire.

We have seen above that the heat produced by a discharge through the electrical thermometer, under otherwise like circumstances, remains the same so long as the quotient $\frac{q^2}{s}$, or what is the same, the product of the electrical quantity q multiplied by the density $\frac{q}{s}$ does not change. But since the same value of $\frac{q^2}{s}$ is always necessary for the ignition of the thin wire, it was to be supposed that the discharges which effect the ignition of the thin wire also produced in the thermometer like temperatures, which, in fact, is very nearly the case in the above series of experiments.

For the sake of brevity we shall measure the current by its heating power, and always denote the quantity of heat produced in a wire, kept constantly in the conducting circuit, by the term *force of the discharge.* This force is constant so long as the value of $\frac{q^2}{s}$ does not vary, other things being equal

2. *Ignition of the wire in proportion to its length.*—When a discharge current produces incandescence in a thin wire, a prolongation of the wire retards the current so that the glow no longer appears.

If an electrical thermometer besides the thin wire be introduced into the circuit, lengthening the wire will also occasion a less heat in the thermometer by retarding the discharge.

Since the "force of the current" is measured by the temperature of the electrical thermometer, it also may be said that the force of the current is diminished by the prolongation of the thin wire.

If, then, a certain charge of the battery brings the wire to ignition, by lengthening the wire, the same charge will yield a current of less force, and it will no longer be sufficient to produce incandescence in the wire. To make the longer wire glow, the charge must be increased, as shown by *Riess'* experiments, until the force of the current has reached its previous magnitude.

A platinum wire 15.7 lines long was brought to incandescence by four jars and a quantity of E 12, the indication of the thermometer being 8.

An equally thick wire, 77.5 lines long, was brought to incandescence by four jars and a quantity of E 22, the indication of the thermometer being likewise 8. Wires equally thick, but of different lengths, were, therefore, brought to ignition by currents of the same force.

3. *Ignition of wires in proportion to their thickness.*—If a given force of current produces ignition in a wire, with an equal value of q and s, a thicker wire of the same length will not produce that effect, although the force of the discharge current increases on account of the diminished retardation.

To produce incandescence in thick wires, q must be increased, by which the force of the current is also increased.

For wires of equal length, with radii of 0.018 in., 0.021 in., 0.026 lines, respectively, discharge currents were required whose forces, measured in the electrical thermometer, were 9, 20, 43.

The fourth powers of the three radii are to each other as 10 : 19 : 45, and these numbers are nearly in the same proportion as 9 : 20 : 43. Hence,

The force of the discharge of an electrical battery, necessary for producing ignition in a wire, is proportional to the fourth power of the radius of the wire.

4. *Ignition of wires of different metals.*—It follows from the experiments that *Riess* made on the ignition of wires of different metals, that if 1 indicate the force of the current required to produce ignition in a platinum wire, wires of the same dimensions, consisting of the following metals, are brought to the same condition by currents as follows:

Metal.	Force of current.
Iron	0.816
German silver	0.950
Platinum	1.00
Palladium	1.07
Brass	2.59
Silver	4.98
Copper	5.95

§ 53. Phenomena following ignition.—If the force of the current is increased more than is necessary for the first incandescence the following phenomena appear in succession with the increasing force. The wire becomes white hot, tears from its fastenings, breaks into pieces, melts, and is dissipated.

1. *Tearing loose.*—A platinum wire of 0.026 line radius and 16 lines long presented the following phenomena:

No. of jars.	Quantity of E.	Phenomenon.
4	12	The wire red hot.
	14	Increased ignition.
	15	White hot.
	16	Torn into three pieces.

According to *Cavallo*, the glow should progress from the positive to the negative end of the wire. *Riess* noticed, with one exception, a reverse progress in every case.

According to *Van Marum*, when the wire is partially destroyed, it is always the part nearest the positive coating that is injured; but *Riess* found the wire broken sometimes at the positive end and sometimes at the negative end.

A wire which has once been brought partly to ignition, is more easily torn than a new one.

2. *Breaking into pieces.*—Wire being subjected to a stronger discharge than is necessary to tear them, they break into a greater or less number of small pieces giving off light, which are thrown to some distance. It may be seen in the collected pieces, that the dismembering of the wire depends upon a splitting and breaking action, and that fusion where it appears is only secondary.

A platinum wire 16 lines long, and 0.079 line thick, was surrounded by a glass tube $7\frac{1}{2}$ lines in diameter, and placed in the conducting circuit. The discharge of the quantity of electricity, 22, collected in 7 jars, brought it to ignition; the quantity 35, tore it into pieces, which were found in the tube. The pieces had evident signs of fusion on their surface, and four of the largest seemed welded together in a twisted figure, which indicated that they were thrown while hot against each other, and against the sides of the tube. The ends of all the pieces were not fused, most of them were sharp pointed. A tolerably straight piece was measured under the microscope: it was 0.081 line in the middle, and at one end 0.022 line in diameter, hence it had been split lengthwise. Other pieces showed the same appearance.

Numerous other experiments gave similar results. By carefully increasing the charge, the shivering of the wire was produced without the least trace of fusion.

3. *Fusion.*—By continually increasing discharges, the wires were broken into less and less pieces, which melted at their surfaces and ends, and at last flowed together, into globules. The wires were in all cases torn violentlyfrom their fastenings, and the pieces scattered

far and wide. All the following experiments were made under a bell glass, and the scattered pieces collected on a sheet of paper at the bottom.

A platinum wire, 0.0258 lines radius, 19 lines long, becomes red hot with $s = 5$ and $q = 11$; with $q = 20$ it broke and melted. Many pieces ½ line long had globules at their ends; a few splinters were melted together. A similar platinum wire melted into a number of small perfectly round globules with $q = 22$.

A silver wire, 0.0264 semi-diameter, 20 lines long, broke and melted with $s = 6$, $q = 26$; some globules and fragments fused together were collected.

A tin wire, radius 0.037, length 15, with $s = 5$, $q = 20$; globules dropped which oxidized in dancing about with the well known scintillations.

A copper wire, radius 0.0253, length 16 lines, with $s = 6$, $q = 20$ ignited; with $q = 25$, was converted into very small globules. Larger globules could not be obtained from copper.

The charge producing perfect fusion here, is not much greater than that which produced the first red heat. Hence, with the oxidizable metals, the temperature is elevated by receiving oxygen from the air, chemical effects uniting with the electrical. This is most remarkable in iron, which often melts with charges, that directly would have produced only a moderate ignition.

An iron wire, radius 0.0266 length 17 lines, came to a bright red heat with $s = 3$, $q = 13$; but this did not cease in an instant, as in the other cases. The ignition increased to a white heat; then some globules dropping from the wire rolled about on the paper, giving off an abundance of sparks.

The residue of the charge remaining in the jar after the fusion of a wire, is very considerable; in one of *Riess'* experiments it amounted to nearly 23 per cent. of the whole charge.

4. *Dispersion.*—The first directly visible effect of the electrical discharge on a new wire, consists, as before remarked, in the formation of a cloud of vapor rising from the surface. It is probable that this consists of particles of metal separated from the exterior of the wire, the quantity depending upon the condition of the surface. By increasing the charge beyond the point at which it would perfectly fuse the wire, it is possible to convert the whole mass of the wire into such a vapor. This takes place with a brilliant development of light, and a loud report.

A platinum wire, (radius 0.0309 lines, length 15 lines,) ignited with $s = 5$ and $q = 13$, and with $q = 17$, melted into globules. A similar platinum wire was dissipated with brilliant light, with $q = 22$, and in the tube surrounding it appeared a gray deposit.

The same experiment was repeated in the open air, and a few lines above the wire a plate of mica was held; it was covered by the dissipation of the wire with gray and blackish flakes, which, under a microscope of 280 magnifying power, seemed to be composed of particles of metal of different sizes and form.

The more brittle the metals are, the more easily are they dispersed.

§ 54. MECHANISM OF FUSION.—Whenever electrical fusion occurs, there is a mechanical separation of the melted mass; hence, this fusion is only the effect of heat upon finely divided metal. The difference between fusion by fire and electricity, *Riess* has characterised as follows:

"When fire acts on a metal, it heats the metal as an entire mass to the melting point; electricity, on the contrary, heats the metal (as a whole mass) only to a temperature below the welding point, and completes the fusion *by simultaneous dissipation and heating.*"

Franklin proposed in 1747, the view, which he afterwards abandoned, that lightning loosens the cohesion of a metal without the aid of heat, and brings about a cold fusion. This view was taken up again by *Berthollet*, who explained the operation of electricity on a substance, by a separation of the particles, and supposed the heat developed to fuse it, as only a secondary phenomenon.

This opinion is in some respects true, according to the experiments just given, but it leaves entirely out of consideration the heat which occurs before the mechanical effect; on the other hand, the view generally held subsequently, that electrical fusion is wholly the result of heating, is just as one sided, for it disregards the mechanical effect.

§ 55. CHANGES IN THE COEFFICIENT OF RETARDATION OF METALS WITH INCREASING MECHANICAL EFFECTS.—We have seen that between the temperature h of a wire, the quantity of electricity q, and the number of jars s, the relation

$$h = n \frac{q^2}{s}$$

subsists, in which n is a constant factor during a whole series of observations. This is no longer the case when a wire in the conducting circuit is affected mechanically by the discharges passed through it and is brought to ignition, as appears clearly from the following results: A platinum wire, 17 inches long, with a radius of 0.0209 lines, being inserted in addition to the thermometer, the result was:

s	q	h	n	
4	5	7.6	1.22	
	7	14.0	1.15	
	9	20.0	0.99	Bending.
	11	27.2	0.90	Red hot.
	13	33.3	0.80	White hot.
	15	41.3	0.95	Melted to globules.

Thus the coefficient of retardation decreases when mechanical effects and incandescence are produced by increased charges, but it increases again by melting.

Riess is of the opinion that the phenomena of heat obtained by a continuous transmission in the wire are produced by the electricity

traversing the wire with uniform rapidity, while the mechanical effects are the result, in part at least, of an interrupted transmission. If the quantity of electricity is too great to be conducted off continuously, it will accumulate in separate places at which its progress is impeded by some cause, until it is in the condition to break through the obstacles. Hence the increase of the coefficient of retardation. The places interrupting the discharge are indicated by the bending. The retardation becomes less again by fusion, because here, at least in part, a disruptive charge occurs.

Different kinds of transmission of electricity take place in non-metallic substances. In discharges through the air, by means of sparks, brushes, &c., an interrupted transmission takes place, while the gradual passage of electricity through the air, recognized in the laws of *Coulomb*, is regarded as the continuous discharge of an electrified body. A battery can be perfectly, continuously, and quietly discharged by a tube of water, but by increasing the charge a spark will appear in the tube, which is broken with violence—discontiuous or explosive discharge.

That the discharge passes through water in different ways is shown most distinctly by introducing the thermometer, together with the tube of water, into the circuit. With four jars the result was:

Amount of E.	Temperature.
5	0
5½	0
6	0
6½	27.5
7	35.

As long as a continuous discharge takes place in the water, the discharge is so much retarded as to indicate no heating; but with a slight increase of the charge the rupture of the tube is made, and with it a sudden elevation of temperature in the thermometer.

[TO BE CONTINUED IN THE NEXT REPORT.]

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